Overcoming Barriers to Collaborative Research: Report of a Workshop

Government-University-Industry Research Roundtable

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Overcoming Barriers to Collaborative Research

Report of a Workshop

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

The purpose of this report is to contribute to the discussions of how universities and industry can overcome barriers to collaborative research. The views expressed are those of the symposium participants, and do not represent official policy statements of the Government-University-Industry Research Roundtable and its sponsoring organizations, the National Academy of Sciences, the National Academy of Engineering, or the Institute of Medicine.

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Executive Summary

This report summarizes discussions and insights from the workshop on Overcoming Barriers to Collaborative Research held March 23-24, 1998, in Irvine, California. The workshop was organized by the Government-University-Industry Research Roundtable of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine. The purpose of the meeting was to discuss barriers to university-industry cooperation and to explore concrete approaches to overcoming them. Practitioners from universities and industry, as well as government policy makers, participated in the two-day workshop.

It is hoped that the workshop and this publication will contribute to wider dissemination of constructive approaches to problem resolution and build broader appreciation of creative pathways around stumbling blocks. The report summarizes the context of workshop discussions, trends in university-industry collaboration, barriers, and possible future tasks. Also included as appendixes are the presentations of Teri Willey and Francis Via, who are experienced technology transfer professionals. These presentations were chosen for their practical university and industry perspectives on the relevant issues.

Given the scope of the project, a comprehensive examination of university-industry research collaboration and related issues was not possible. It is hoped, however, that the workshop and report will contribute to further efforts in this important and complex area.

The report was reviewed by those who made presentations and by several other experts. They provided many useful suggestions, but the report is not a consensus document or conference proceedings.

TRENDS IN UNIVERSITY-INDUSTRY COLLABORATION

• Participants noted that university-industry research collaboration is becoming more frequent and extensive, with growing complexity in individual partnerships. Over the last two decades, industry-supported research has steadily grown nationally in amount and as a percentage of all university research.

- A number of collaborative mechanisms were discussed, including (1) university research sponsored by companies; (2) faculty consulting; (3) licensing of university-owned intellectual property to existing companies; (4) university support for start-up companies in the form of loans, grants, and equity ownership; (5) "mega agreements" between individual companies and universities that cover a range of interactions; (6) research centers and other government-supported efforts to encourage university-industry collaboration; and (7) industry consortia to support university research.
- There is significant diversity in the approaches taken in different fields. Participants remarked on differences between industry-university collaboration in health care and the life sciences vis-à-vis physical sciences and engineering. Most of the discoveries that have produced significant licensing revenue for universities have been in the life sciences.
- Participants noted that a growing array of rules, procedures, and institutions, particularly on the academic side, govern collaboration. Protecting and managing university-generated intellectual property has become a significant task, and some institutions are delegating this work to non-profit and for-profit subsidiaries.

BARRIERS TO COLLABORATION AND TOOLS TO OVERCOME THEM

- **Culture, management, and goal alignment.** Despite the long experience that many companies and universities have in pursuing collaboration, workshop participants still considered the development of trust an essential but sometimes neglected precondition for success. The discussions covered tools for structuring and managing partnerships and approaches to reconciling different time horizons.
- **Institutional incentives.** University and private industry incentive structures may not sufficiently recognize or reward the key contributions that ensure successful collaboration. Workshop participants discussed ways that incentive structures could be changed with funding mechanisms and evaluation systems that are better targeted.
- **Proprietary rights.** Issues of proprietary rights and their disposition were a special focus of the workshop. Proprietary rights issues are often linked to other areas such as project management and incentives. There was

a broad range of perspectives on the issue of how aggressive universities should be in patenting and licensing their inventions. The participants also covered such issues as the patenting of research tools, the structure of university technology transfer operations, and agreements on confidentiality, and delay of publication.

POSSIBLE FUTURE TASKS

• Participants made a number of suggestions on possible future tasks. Many participants believe the policy framework for university-industry interactions established by the Bayh-Dole Act, formally known as the Patent and Trademark Laws Amendments of 1980, is working well, while a few participants believe a fundamental reconsideration of that law is in order. Technically, the Bayh-Dole provisions influence university-industry collaboration only when a university invention is developed using federal funds.

• Individual participants suggested that key industry and university bodies consider development of (1) accepted standards for training and credentialing of university and industry technology transfer professionals; (2) a statement on acceptable indirect cost practices in university-industry research, which may need to address the government's role; and (3) a declaration of principles concerning responsible conduct in industry-university research collaboration.

• Several participants stated that further study and exchange of ideas on the way universities successfully structure technology transfer operations would be useful. Similarly, a detailed examination of industry effective practices in research collaboration with universities would be helpful. These exercises could also explore whether there are areas in which pursuit of proprietary rights is counterproductive for all concerned.

Chapter 1

Introduction

As universities confront diminishing growth in federal funding for research and development (R&D) and industry faces increasing pressure to focus internal R&D on short-term payoffs, new partnerships are emerging that would coalesce to change the roles of universities, industry, and government in the R&D enterprise.[1] Many companies are now pursuing longer-range strategies through collaboration with universities and other external R&D resources. As a result, collaborative research partnerships have multiplied and diversified enormously in recent years.

Since partnerships first began to emerge dramatically in the 1980s, well-documented studies have provided strong evidence of their benefits. According to J. David Roessner of the Georgia Institute of Technology, "The question is not whether increased university-industry collaboration can yield desirable outcomes for all concerned: clearly, it can and often does."[2]

Just as the value of research partnerships has become clear, barriers to effective partnering have also become apparent. While it is true that certain academic institutions and companies have learned to organize and manage collaborative programs with a high degree of sophistication, other organizations have faced recurring barriers. Wider dissemination of constructive approaches that have been devised in specific cases can lead to a broader appreciation of stumbling blocks and creative ways around them. Barriers relate to the following aspects of collaboration:

- disposition of intellectual property and "background" rights;
- publication, copyright, and confidentiality concerns;
- regulation, liability, and tax law issues;
- various worries regarding foreign access;
- matters of graduate student involvement; and
- infrastructure-related impediments to inter-disciplinary and inter-departmental research.

In March 1998, the Government-University-Industry Research Roundtable, in cooperation with the Committee on Science, Engineering, and Public Policy organized a workshop to discuss barriers to university-industry cooperation and concrete approaches to overcoming them. The Research Roundtable is sponsored by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The workshop was designed to bring together a small group of individuals with extensive experience in formulating and managing collaborative research across sectors (see agenda in Appendix D). The discussion featured real-life examples of institutional experiences, with emphasis placed on sharing the outcomes of policy and programmatic decisions. This report covers the major themes and insights from the workshop; it is not, however, a comprehensive study of university-industry collaboration. Those persons who made presentations also reviewed the report and provided many useful suggestions; the report should not be viewed as a consensus document or conference proceedings.

This activity reflects the Research Roundtable's longstanding interest in fostering dialogue to achieve the maximum national benefit from effective university-industry research interactions.[3] The workshop was supported by three federal agencies that have programs featuring collaboration across research sectors: the Department of Commerce, the Department of Defense, and the National Science Foundation.

Chapter 2

Trends in University-Industry Research Collaboration

University-industry research collaboration has a long history in the United States. Unlike the university systems of many other countries, the U.S. system is decentralized. A primary mission of American universities from their earliest days has been to provide graduates with the skills needed by local economies.[4] Early research collaboration often grew out of the local orientation of a university's educational mission.[5] The development of electrical engineering, chemical engineering, and aeronautical engineering in the late nineteenth and early twentieth centuries was centered on universities. Many of the modes of interaction that are familiar today originated before World War II (e.g., start-up companies based on university research, university-industry-government research centers, faculty consulting, and licensing of university-generated inventions). However, the postwar period witnessed explosive growth in U.S. research and development (R&D) and expansion of the university role in research.

Over the last two decades university-industry collaboration has grown considerably. One impetus has been the Patent and Trademark Laws Amendments of 1980 and subsequent revisions, commonly referred to as the Bayh-Dole Act, which rationalized and simplified federal policy on patenting and licensing by non-profit institutions of the results of publicly funded research.[6] Most significantly, Bayh-Dole granted control to universities of most proprietary rights emerging from federally sponsored research. A second contributing factor was the emergence of revolutionary advances in university-based life sciences research. Today, industry funds about 7% of university research, about double that of 20 years ago, and various indicators of university-industry interactions show continuing rapid growth.[7] Appendix C spotlights some of the examples discussed at the workshop.

Collaboration involves many more rules and procedures to define and protect the interests of the parties than it once did. There were different perspectives on whether this is a positive development. Clearly, an "anything goes" approach is not practical, given strong public and private interest in orderly development. The emergence of more rules, procedures, and institutions to implement them (such as university technology transfer and licensing offices) can be considered a result of the incentive structure put in place by Bayh-Dole. If universities are to be responsible for management of a portfolio of intellectual property generated through federal research funding and can foresee use of the resulting revenue for academic purposes, it is natural that they would develop procedures and institutions to carry out those roles.

Several participants felt that the approaches taken by some universities are too bureaucratic or adversarial. One industry participant remarked on a "loss of trust," and saw universities as becoming focused more on income from licensing and royalties than on the goal of getting inventions into active development and use. Several participants noted that most university technology transfer operations do not break even and that only a small proportion of inventions (mainly in the life sciences) accounts for a large share of income. Given this context, elaborate strategies to maximize income on individual arrangements may not speed the movement of the majority of ideas into practical use—and may actually be destructive.

Several university participants responded that their institutions are doing their best to manage technology transfer activities in ways that maximize the public benefit. They see the approaches of some companies and other funding entities in the intellectual property rights area, such as the pursuit of extensive rights to university background research developed outside the collaboration, as stumbling blocks. The barriers raised by complex proprietary concerns, and possible solutions, are discussed further in Chapter 3.

Participants also discussed trends in the form and substance of collaboration. For example, as the funding criteria change for programs such as the National Science Foundation's Science and Technology Centers and State/Industry/University Cooperative Research Centers, we might expect to see more multi-university centers. Master agreements between universities and large companies that establish the ground rules for a range of specific interactions are also on the rise. Amgen, Inc.'s master agreement with the Massachusetts Institute of Technology and Carnegie Mellon University's agreement with Caterpillar, Inc., were discussed as positive examples.

Chapter 3

Barriers and Lessons of Effective Practices

One theme from an earlier meeting on collaborative research organized by the Research Roundtable, the Industrial Research Institute, and the Council on Competitiveness was that structuring and managing partnerships that produce real gains for all partners takes experience, careful planning, and ongoing attention.[8] At the March 1998 workshop, attendees discussed barriers to collaboration and the approaches that have been developed to overcome them. It was not possible to cover all issues comprehensively, and the discussion revealed several issues on which important work could be done in the future.

In this chapter the issues are divided into the following categories, which are often interrelated.

ISSUES OF CULTURE, MANAGEMENT, AND GOAL ALIGNMENT

Partners may lack understanding or trust. In some cases partners enter into agreements with an inadequate understanding of the management, internal politics, decision-making structures, and even fundamental interests of the other partner, resulting in slow decisions and insufficient resources.

Possible solutions. The importance of building trust between partners and effective "relationship management" emerged time and again during the workshop. The right mechanisms may depend upon the scale and substantive focus of the collaboration. For example, large mega agreements may require regular meetings among senior management of the company and university, as well as regular exchange at the bench level. Eugene Slowinski of Rutgers University described several specific techniques that could help bring potential problems to light at the negotiation stage: stakeholder mapping (in which stakeholders in each organization are identified), decision-making analysis (in which the decision-making processes of each organization is made explicit), and expectation mapping (in which the expected roles and contributions of each partner are analyzed).

Industry and universities often have different time horizons. Industry and universities have different time horizons for good reasons. Although some senior management officials in industry are concerned that universities are becoming too short term in pursuing specific projects and collaborations, industry is generally operating on a shorter time horizon than academia. In some cases discussed during the workshop, industry partners were seen as disruptive by universities when industry pulled out of projects on short notice or hired students in the middle of degree programs.

Possible solutions. For broad collaboration (master agreements) and focused collaboration (clinical trials), misunderstandings of the preceding type appear to be uncommon. More commonly, problems arise with projects with less well-defined outcomes than clinical trials. Several participants noted that universities should avoid overselling in terms of potential accomplishments and timelines. Likewise, industry should understand that, in most sponsored research, the effective time unit is the time it takes to complete a Ph.D. dissertation, usually three years. Although some companies are exploring the possibility of sponsoring university research with a faster turnaround, it is unclear whether it can become a standard practice.

ISSUES OF INSTITUTIONAL INCENTIVES AND INTEGRATION OF RESEARCH AND EDUCATIONAL MISSIONS

Institutional reward structures may act as disincentives to collaboration. In some cases, because key staff members of the industry partner may not be rewarded financially if the project succeeds, the staff members assign collaboration a low priority. Financial rewards resulting from collaboration are more likely for university faculty members. On the other hand, collaborative work can impede young faculty members from getting the intellectual recognition necessary to gain tenure. In one example discussed at the meeting, a young faculty member spent a great deal of time and effort on a collaborative project, probably undermining her chances for tenure.

Possible solutions. Companies have assigned liaisons with project responsibility, resulting in management of collaborative work being included in employee performance evaluations. Often, these are researchers who are working on a similar in-house project. On the university side, participants reported that it is possible to structure tenure decisions and other promotion processes in ways that give faculty credit for being effective collaborators with industry. Industry partners can be asked for an evaluation, for example. Government can also play a role through its funding decisions. The National Science Foundation's Engineering Research Center and Science and Technology Center programs have encouraged partner universities to create mechanisms to recognize effective collaborations.

In recent years, a number of universities have sought to implement innovative incentive structures by starting or expanding programs aimed at facilitating the launch and growth of start-up companies based on university research. Such structures include university-managed incubator facilities, provision of seed funding in return for equity, and focused efforts to attract management talent and catalyze company formation. In Appendix B Teri Willey discusses ARCH Development Corporation, which has been undertaking these efforts for a number of years. A university moving in the opposite direction is the University of Arizona, which settled a patent suit brought by a start-up several years ago and now licenses technology to only established companies.[9]

Student time may be misused and conflicts of interest may arise. When a faculty member holds an equity stake in a company that sponsors university research and has graduate students working on that research, tensions and suspicions can arise. In one case, a faculty-owned company hired graduate students as consultants, blurring the distinction between student and employee. The university-based participants in the project later considered this arrangement a mistake.

Possible solution. Participants reported that experienced universities had developed policies to deal realistically with these issues. Although some faculty members may wish to minimize involvement in collaborations by the university's research administration and departments, others assert that open communication with these bodies can prevent abuses, as well as suspicion and misunderstanding about such arrangements. Some universities and departments simply do not allow students to become regular or part-time employees of research sponsors.

Industry may seek to stretch resources by not paying indirect costs and faculty may pressure the university to agree. Given the substantial indirect cost rates of research at universities and elsewhere, it is understandable that some persons in industry are reluctant to pay, or wish that all the funding be used only for research. If indirect costs are waived on industry research, however, they must be made up somewhere else (e.g., tuition or other research grants).

Possible solutions. Several of the industry participants recognized the need to pay indirect costs, and creative approaches have been developed to increase incentives to do so. For example, some universities have traded current overhead recovery for a greater share of downstream royalty income or for equity. Care must be taken, however, because indirect costs are current and downstream income is uncertain, and any trade-off must not short-change another part of the university.

Another example is the state of California's Microelectronics Innovation and Computer Research Opportunities program, launched in 1981. For approved projects, California puts up a third of the funding, the company puts up a third, and the University of California campus involved waives overhead on the industry and state funding, essentially providing another third. University participants reported that this approach has been very successful in encouraging a broader range of companies to support research.

This topic deserves more examination than was possible during the workshop. A future examination may need to take the position of the federal government into account.

ISSUES OF PROPRIETARY RIGHTS

Are intellectual property rights an inhibiting factor in research collaboration? Several of the industry participants saw some universities increasingly taking too restrictive an approach to licensing and putting too high a value on their intellectual property contributions. Industry is increasingly seeking out second-tier U.S. universities and foreign universities for collaboration when they perceive first-tier universities to be too difficult to deal with. Some university boards of trustees may see technology transfer activities more as a revenue source than as a component of the university's public responsibility to assist in commercializing research results. This attitude can raise barriers to negotiations that actually reduce revenue over the long term. Given that only a small percentage of university-generated inventions produce significant revenue, some participants likened the strong emphasis on protecting proprietary rights of some universities to "buying lottery tickets."

Most of the discussion of this topic and suggestions from both industry and university participants focused on issues related to the university side of collaborations. There was also recognition, albeit with less detail and fewer examples, that the effectiveness of industry approaches also has a major impact.

Possible solutions. Participants expressed a broad range of views on this issue. It is important that faculty, as well as university and industry leaders, understand that the role of intellectual property in the innovation process varies by field. Approaches that make sense in the biomedical field may not make sense in engineering and computer science. Several participants suggested that universities consider forgoing all proprietary rights outside the biomedical area, essentially putting inventions in the public domain. Other participants responded that many universities do not seek patents on their inventions unless an industry licensee has been identified, and that this approach is more likely to facilitate commercialization than a blanket policy of not patenting inventions outside the life sciences. To many participants, the main issue is whether universities manage their technology transfer roles to comply with the intent of the Bayh-Dole Act by enhancing the use of university-generated inventions. Several speakers believe that a well-run technology transfer operation governed by a realistic university policy can do this more effectively than a general policy of putting inventions in the public domain.

In addition to university licensing policies, premature definition and valuation of intellectual property can become an obstacle at the initiation stage of a collaborative project. Granting the company the right of first refusal to negotiate an exclusive license is one commonly used practice to delay concrete negotiations until the commercial value of an invention is easier to assess.

Patenting of research tools may discourage beneficial research. This topic increasingly appears to be an issue in the biomedical area. For example, different universities may hold patents to different receptor cells of the same class that influence a disease process. To start a research program it would be necessary for a company to license the rights to all these receptors. If each university demands a 1% or 2% royalty, the company may not find it feasible to go forward with the program due to high transaction costs or the prospect that the overall royalty will be too high.

In one case described in the workshop, related receptors were developed by a university with federal funding and were licensed exclusively to the university's for-profit subsidiary. When a company inquired about licensing the receptors, they were told that they would need to sponsor research at the university as a condition. One industry participant noted that companies have been fairly receptive to the use of their research tools in the past, and wondered whether the companies would be less so in the future.

Possible solutions. Universities and industry should both want the widest possible use of research tools. Licenses that carry low rates until an invention generates a certain level of income have been used in some cases. One industry participant urged universities not to patent partial gene sequences and research tools at all, since it might be very difficult to prove infringement. There was some discussion of universities defining a "deminimus threshold" for an invention before a university would seek a royalty-bearing license.

Publication delays and non-disclosure requirements may impair the openness of the university research environment. Companies sponsoring research often need time to evaluate whether applying for a patent is worthwhile, and ask universities to delay publication of results. Such delays can impair the open research environment or prevent junior faculty from building a strong record of publications needed to gain tenure.

Possible solutions. There is clearly a wide range of practices among universities in this area. Some do not allow any delays in publication. Many allow publication delays of 60 to 90 days. One university allows a delay of up to two years on a case-by-case basis if no graduate students are involved in the research and non-tenured faculty members sign a statement indicating that they understand the policy. Despite these diverse approaches, a number of participants seemed confident that effective ways of handling these issues are widely available. In the area of non-disclosure, one industry participant reported that in the rare instances when there is a need to share confidential information with a faculty member, this can be done with a consulting agreement separate from the sponsored research agreement.

Chapter 4

Possible Future Tasks

Participants discussed a number of suggestions for follow-up, a selection of which is briefly discussed below. The project scope did not allow a comprehensive examination of all relevant issues and alternatives. It is hoped that the ideas raised at the workshop will be useful to other groups examining this complex and rapidly changing field, such as the Business-Higher Education Forum, Association of American Universities, Association of University Technology Managers, Council on Competitiveness, and the Industrial Research Institute.

• **Rethinking of the Bayh-Dole framework.** Perspectives were divided on this issue. Although technically the Bayh-Dole Act is relevant to university-industry collaboration when a university invention has been developed using federal funds, the legislation has fundamentally changed how many universities and companies approach collaboration. Many participants believe that the Bayh-Dole Act has facilitated a great deal of valuable collaboration between industry and academia, and it would not be possible or desirable to go back. In this view, barriers are best overcome through dissemination of best practices and through initiatives in the research community to deal with common stumbling blocks. Several other participants were skeptical that Bayh-Dole has been that beneficial, and believe that some basic rethinking is justified.

• **Development of "accepted standards" for university and industry technology transfer professionals.** Some participants believe that a common source of barriers to collaboration is inexperience of the technology transfer staff members in universities and industry. Although the level of expertise has risen in this relatively new profession, some suggested a focused effort on the part of the Association of University Technology Managers, along with academic and industry associations, to develop professional standards in such areas as training and credentialing.

- **Develop a statement on acceptable indirect cost policies in university-industry research.** Several participants said that it would be useful for a respected group to further study and perhaps develop a statement on appropriate policies for waiving or modifying indirect costs on industry-supported research. The federal government's role may need to be addressed in such an activity.

- **Develop a statement on the responsibilities of industrial partners in research collaboration.** One participant asserted that a statement on the responsibilities of industrial partners would be helpful to universities and industry. Workshop participants related several instances of industrial partners pulling out of collaborative arrangements abruptly or hiring students away in the midst of their degree programs. Further study and a statement on commonly accepted responsibilities could help partners avoid these situations.

- **Further study of university and industry effective practices in research collaboration.** In light of the different approaches that universities and companies are taking, one participant suggested that a continuing effort to evaluate the effectiveness of these approaches would be useful. For example, some universities are delegating technology transfer activities to non-profit or for-profit subsidiaries. Likewise, some companies are seeking to work with universities on projects with a shorter time horizon than has traditionally been the case. How can such cooperation be managed effectively? Such an examination might also take up the matter of whether universities should consider not patenting in certain fields.

Appendix A

Presentation by Francis Via Director of Contract Research, Akzo Corporate Research[1] at the Workshop on Overcoming Barriers to Collaborative Research March 23-24, 1998

I would like to provide a brief overview of an industrial approach for leveraging resources by conducting cooperative research with university and national laboratory partners.

First, let us consider a few general descriptors for research partnerships in the chemical industry: why we do it, what is it we expect to gain from such partnerships, and what industry-wide issues are fostering this approach? Partnerships for research with universities are growing at the rapid rate of nearly 20% a year.

Why is this activity occurring at this advanced stage of development of this industry with such a strong economic foundation and a large influence on the GDP? Furthermore, what are the goals of these programs? To answer these questions, we need to look at the industrial drivers that are impacting research. We will also briefly review the implications for partnerships, and the impediments to progress.

By way of introduction, Akzo Nobel is a multinational corporation with U.S. headquarters in Chicago and the U.S. corporate research center in Dobbs Ferry, New York, just north of New York City. World headquarters are in the

[1] This is an edited transcript of the presentation. Current address: Francis A. Via, Manager, Catalysis Program, Chemical Process Technology Laboratory, GE Corporate Research and Development, CEB-423, P.O. Box 8, Schenectady NY 12301. 518-387-5490, francis.via@crd.ge.com.

Netherlands. As with most multinational corporations, we are proud of our American citizenship. Most every chemical sold in the United States is manufactured in the United States, although there are a few exceptions. Akzo Nobel is a net exporter of chemicals from the United States, and we are pleased to emphasize this point each time we negotiate a cooperative program with a national laboratory or government agency.

Furthermore, relative to globalization of the chemical industry, Department of Commerce data show that one-half of the 1 million U.S. employees in the chemical industry are employed by companies with foreign ownership. This impact is greater than is commonly perceived. We certainly have achieved a globalized economy for the chemical industry, and that is now placing greater impact on research strategy. The funding of industrial research is analogous to the employment situation. About 45% of all the chemical industry research conducted in the United States is funded by companies with foreign ownership. This commitment is a very strong testament to the value of the U.S. research infrastructure. Global corporations have an active presence in the United States not only for the markets, which were the initial primary driver, but also for the research infrastructure; the students, consultants, universities, national labs, and so forth.

What are the industrial drivers that are now affecting research investments? Strategies for research investments are similar to those of other investments for manufacturing, distribution, and marketing. The principal metric is risk versus return for our technology-intensive industry. Furthermore, the perception commonly accepted by the financial community that the chemical industry offers only modest growth potential has impacted research investments. This relative assessment has had a profound impact on the type of research that is funded.

Globalization is a dominant driver and, as a result, there are no safe geographic or product niches. This situation is similar to the automobile industry. The chemical industry is experiencing intense global competition. For example, when I first started my research career more than 20 years ago, there were many attractive specialty markets, for example, flame-retardant materials, specialty surfactants, functional lubricants, and so forth. For each of these markets there were essentially three or four major manufacturers. One company might gain nearly 35-45% of the market. The other two or three would split the rest. Thus, there were attractive margins, and you could conduct research in a fashion that would reflect those margins. Now, there are nearly 14 suppliers of some of these specialty chemicals and that intense competitive situation is fostering a shorter-term metric for the accountability of research.

The equity markets represent another driver. There is a perception that Wall Street is only looking for quarterly returns. In reality, they are looking for balance to see that you are really protecting your long-term profitability and sustainability, while focusing on short-term returns. This influence of Wall Street is reflected in shorter-term approaches to research by the chemical industry.

Risk, liability, and regulations are also influencing the type of research being pursued. As a result, industrial research in the chemical industry has taken a defensive posture. Changes in the stability of the organization, brought about by downsizing, right sizing, mergers, and other trends, have also pushed middle managers and middle-level vice-presidents to become more risk averse than their predecessors.

So, how have all of these factors influenced chemical research, and why do we need partnerships?

Most significantly, central research organizations have been shrinking for many U.S. manufacturing industries—chemistry, in particular. There has been a greater customer focus. In fact, if you walk through our laboratories, at times it will look like it is only partially occupied because many of our scientists are visiting customers. An inspection of our research travel records will show frequent trips to customer research sites. Thus, with a generally shrinking R&D budget, a strong customer focus, and the need to lower manufacturing costs and ensure environmental compatibility, a new role for our central corporate research is emerging. That new role is to help the corporation define its research strategy and identify new lower-risk approaches to innovation. We are actively leveraging resources to get more with less, as well as monitoring and assessing new emerging technology. It is surprising how widely recognized this trend is becoming, not just in industry publications, such as *Chemical and Engineering News*, but even in the general media.

To address these issues and to satisfy it's internal customers, industrial research is becoming more receptive to external collaboration, which naturally follows from wanting to reduce risk and from the need to do more with less. What do we expect to gain from partnerships? As we discussed in our breakout sessions yesterday we are looking for knowledge and concepts from high-risk exploratory new technology areas that can impact core businesses. It is more difficult to justify that type of research with today's expected return metric for internal industrial R&D. Collaboration can bring new and different perspectives, as well as increase R&D flexibility. Industrial research managers and scientists need to explore new technologies that they may not have in-house, and if this new approach does not work out they must avoid being saddled with high risks and responsibilities.

Other motivations for collaboration are to build long-term associations and motivate internal scientists. Scientists that spend a large portion of their time working on these short- or intermediate-term programs are highly motivated by the opportunity to explore new knowledge, new concepts, and longer-range, game-changing issues, especially with world-leading research teams.

What are the impediments that we see? Again, we have discussed these yesterday. At the top of the list is trust. When I shared my list of issues with participants at lunch yesterday, there was some concern that trust is too obvious and too simplistic to identify. From our experience, it remains one of the key issues. It is essential to find a partner who we can work with effectively at a university, national lab, or another company. At all costs, we want to avoid resorting to legal remedies.

After the issue of trust, key factors that act as barriers to collaborative research include publication issues, intellectual property, timing, and funding. One of our ongoing projects illustrates the intellectual property issue. This collaboration involved several universities and national laboratories. The goal of this program is to eliminate or remove chromium from anti-corrosion coatings. While this goal has been achieved for many products, the coatings industry is still seeking an anti-corrosion additive for some industrial paints to make them more environmentally friendly and to make their substrates more recyclable. We started a research program to identify new conductive polymers or conjugated polymers that could replace metal additives in these coatings systems. The research team started with an agreement with NASA through the Kennedy Space Center. As with all programs, we try to link our corporate research program with a business unit program. Thus we combined the research efforts of Akzo Nobel's central research in Dobbs Ferry, New York, with the Coatings Research Center in Columbus, Ohio, and Automotive Coatings Products in Troy, Michigan.

The Materials Science and Technology Division of the Los Alamos National Laboratory was a key participant and prepared initial samples for evaluation. We then added researchers at Drexel University to look at the effects of molecular weight and changing structure, and at Polytechnic

University for critical organic synthesis to look at monomers and dispersants. The team grew with the addition of Ohio State for mechanistic characterization. The Navy research group in Orlando joined to help with the evaluation and to address their special interests. This multiplicity of players was a result of networking and identifying growing needs.

How do you trace the actual inventorship in these activities? Akzo Nobel together with each partner established a research contract clearly indicating intellectual property ownership by the inventing institution or institutions and for joint inventions, of which there are several. The contracts also indicated that the total royalty we could possibly afford for a paint product was about 1-2% and each institution should be prepared to share this total for multiple ownership. The competitive markets of industrial coatings limit margins that require all participants, including the industry partner, to review and approve modest royalties in return for a higher probability of success and a potential for a continued research program.

In the initial program phase, our team linkage was rather weak. Everyone had a different opinion on approaches and strategy. It required more than one year to developing a mutual understanding and an effective team. Patience and a personal commitment from each member are essential components of successful research partnerships.

Thus collaboration will likely face many challenges with even the best of partnerships. Our team members at universities work in a generally defined area, with a high degree of freedom and accountability. Frequently, our partners develop a strong desire to race down the line to issues close to product development, an area outside their expertise. Product development research often appears rather straightforward and a fertile area for intellectual property development. Since it is commonly perceived that this area is highly profitable, university researchers may feel limited when industry partners encourage continued exploratory research to establish an understanding and backup candidates. In most cases the industry partner brings a wealth of capabilities for advanced product development related to their core technology and cannot commonly share this information. Industry is best suited to take a molecular concept and carry it through the paces of a product development program.

What are the other key impediments? Let's revisit the issue of intellectual property and share successful practices. Clearly, Akzo Nobel, like most industry partners, understands that universities are the owners of the technology discovered in their laboratories by students and faculty members. We have been successfully operating with that basic understanding for more than 200 programs. Akzo Nobel will cover the cost of protecting intellectual property. In fact, we frequently have our attorneys write the patents for the university. Under the contract we want to write the best possible patent, as both partners will benefit over the long run from this practice. In return for funding the program and covering the cost for securing and protecting intellectual property we request the right of first refusal for an exclusive license, without a time limit and without limitations for the field of use in chemistry, as long as we are funding the program.

Secondly, the contract contains provisions to negotiate a royalty-bearing license. A ceiling is placed on the royalty rate for the designated field of use. In some cases, this ceiling can become a controversial part of the contract. A ceiling is essential as many programs are transferred to a business team during the later stages of the university research. This successful transfer is based on a preliminary economic assessment that includes a royalty accounting. Without this transfer to a business unit, the entire concept of external research will quickly come into question.

Timing is also important. We usually try to fund a project for three years, and frequently renew it for one additional cycle. After the university program is completed, we may seek an extension of the right of first refusal to continue internal developmental work. As the technology approaches commercial development, negotiations for royalty payments are finalized according to provisions of the research contract. In situations in which Akzo Nobel chooses not to continue commercial development, our rights to this technology are relinquished to the university.

The next area of potential contention is publications. This can be rather straightforward. The industry partner requires three to six months to review the publication and to initiate any justifiable patent applications. It is important to appreciate that this rapid approach represents a sacrifice for the chemical industry sponsor. In our industry, one patent rarely constitutes an innovation for a profitable product. Many times, any early publication can alert competitors to a new fertile area of research. For a comparable internal research program, an initial lead can be protected from public disclosure for several years to expand the technology and to develop a strong family of patents. Industry recognizes the need for rapid publication by the university partner with a review system as described above. Delaying of publication for review will provide an 18-month lead for the industry partner. A growing number of universities also wish to protect intellectual property, and consequently the industry partner is provided additional development time, on a case-by-case basis. Mutual trust is critical at this phase.

For the next issue—confidential information and the university environment—we do not commonly include special confidentiality clauses in most of our contracts. As a practice, we do not share confidential information with the university and the professor. With collaborative programs, we are seeking new and different technology. Thus, details of our current technology are not relevant. There are some exceptions, for example, in the characterization of new compounds or catalysts with state-of-the-art equipment, such as the synchrotron light source, to learn details of atomic structure. In those rare cases, we will provide a sample of one of our refinery catalysts under a secrecy agreement with provisions for returning the sample.

The next issue I would like to review today is funding. As I mentioned, we look to fund collaborative research activities for at least two to three years. In addition, overhead is an essential component of a payment agreement. Your partner maintains a research facility that must include essentials like heat and ventilation, hoods, chemicals, communications capabilities, and so forth. We assume that part of the overhead is committed to these essentials.

For program management, we assign a scientist to each project who is identified as the technical liaison. That scientist is working on a similar or related project internally. The technical liaison monitors progress and provides guidance. Although formal review meetings are scheduled every six months, the technical liaison maintains relatively close contact by visiting the partner every 6-12 weeks and through more frequent conference calls when warranted. In addition, the program generally requires external information to guide and help it along. We find today's principal investigators at universities are highly taxed with a variety of responsibilities. So we provide guidance to the patent literature and communicate on other issues more directly with the students.

So far this morning, we have been focusing on one type of partnership—concept development research at the early stages of the project. We are now seeking ways to start using partnerships with universities and national laboratories in areas closer to product development to move ideas to the market more quickly. We have reservations about this approach, as it appears to be incompatible with the scope and charter of a university. There is a need to move more quickly to the market with new concepts. We are continuing to experiment with several strategies to achieve this goal. Of course, the topics and scientists must be amenable to this objective, such as catalysis research at universities and national laboratories.

Faculty consulting helps build long-term relationships and trust while expanding our knowledge base. As you well know, from your own experience and from the example we used with the NASA program, we have a number of professors who continue to serve as consultants and are part of our "technical family." As is common practice, we share inside results to gain the full benefit of their insight, knowledge, and experience. The consultant does not need to share this information with the graduate students, even when involved in a related cooperative program, as the university targets are defined to address new or different technology approaches to the same target. For these cases standard consulting agreements are used. The key focus is "people"—getting the right people together at the right time to accelerate technology development.

Generally, the chemical industry is becoming more receptive to company cooperative research partnerships in order to reduce risk and leverage resources and capabilities. In fact, several government agencies, such as National Institute of Standards and Technology in its Advanced Technology Program (ATP), are serving to further promote this trend. Joint ventures, mergers, and business alliances are not uncommon in the chemical industry. This activity is frequently set up between customers and suppliers and in special cases is spreading to include potential competitors.

Another challenge for research partnerships is maintaining productivity over the life of the project. When we are considering launching a project, we invite a potential partner—professors—to the research center for a day of discussions and a seminar. This activity is designed to help each partner determine the opportunities, strengths, and challenges of an alliance. We do not use a competitive approach at this stage. If both partners believe a win-win situation is likely, we request a formal proposal from the professor. More often than not, the proposal will need further development. After a few iterations, the partners have learned to work together and appreciate their relative contributions. Akzo Nobel will usually fund about 70% of proposals personally requested after a site visit. There are some delays for contract negotiations, discussions, and proposal details. So, by the time the agreement is signed, we hit the ground running. In some cases our partners have actually even started the work and productivity rises very quickly.

One sensitive issue with research partnerships that we have been attempting to address is that productivity appears to drop about midway through a program. This trend, for the most part, is independent of the program length—one, two, or three years. At this midway point, the partner must begin searching for funding to continue after our agreement. Akzo Nobel has frequently renewed programs for a second term, but nonetheless as the departure or termination time approaches, each partner must plan to move on. This activity has a strong influence on research productivity. Thus, each program should be initiated with a clear exit plan to help minimize the reduced productivity in the later stages.

As indicated above, both partners need to benefit for this trend to grow. On occasion the university team can benefit from industrial guidance into a new application area. Our program on conductive polymers exposed university colleagues to anti-corrosion technology. This knowledge base served our partners well and after the external part of the program was completed they successfully secured grants from the Air Force and NSF that allowed continuation of fundamental studies, while addressing the agencies' needs.

How should we as a nation sustain these efforts? In the long run, the university and national lab researchers must continue to develop fundamental knowledge and educate students. As a research partner, we participate in the funding and guiding process for a fixed period—one, two, three or six years. Without an exit plan, academic or national laboratory colleagues may become disappointed with the industrial partner.

From the industrial point of view, another barrier to partnerships is the funding uncertainty and multi-year changes of direction that arise from the cumbersome budgeting process of the national laboratories. We must be able to develop a better way to work with the outstanding scientists and facilities at the national laboratories.

The next issue I want to raise is government technology challenges. We really think partnerships are required for both science and technology. This goal is the orientation of ATP. The government should be supporting both basic science and a balanced portfolio of programs in areas of national needs. We are very interested in the new Vision 2020 Project developed by the Office of Industrial Technology at the Department of Energy, working together with the steel, the aluminum, the pulp and paper, and the chemicals industries. This activity involves establishing priorities with appropriate representatives of the industry and then funding programs in both science and technology in the designated areas.

Education issues are, without question, among the most critical for our nation to achieve sustainable economic growth in a technology-intensive global market. Partnerships offer possibilities for expanded education via co-op programs in industrial laboratories. Improved recruiting is also a benefit of partnerships.

For a final note, let us return to the issue of globalization. Indeed, today we are all subject of and benefit from global manufacturing and marketing, and now also research. We have programs around the world. During the project on coatings cited several times in this presentation, we needed to have access to one of the user facilities at a national laboratory. At the time, access was difficult, so our university partner gained entrance to a world-class facility at Lund, Sweden. In other programs, we have used laboratories in Germany, Russia, and China for research programs. We are, indeed, in the mist of a paradigm shift in both research partnerships and global research.

Appendix B

Presentation by Teri Willey Vice-President, ARCH Development Corporation[1] at the Workshop on Overcoming Barriers to Collaborative Research March 23-24, 1998

I am going to talk a bit about ARCH Development Corporation as an example of how the University of Chicago is encouraging the use of research results. I will also talk about the Association of University Technology Managers (AUTM) and the things that I think are important in this area of industry-university relationships. And I will discuss some approaches and tools that I think work and some evidence as to why I think they work (Slide 1).

ARCH Development Corporation is a wholly owned not-for-profit affiliate of the University of Chicago (Slide 2). It was formed in 1986 to commercialize certain research results from the University and Argonne National Laboratory (Slide 3). ARCH originally had a $9 million venture fund and formed and invested in 18 companies from the time it was formed until 1995. In 1995, ARCH split into two organizations, ARCH Venture Partners (AVP) and ARCH Development Corporation (ARCH). ARCH Venture Partners is now a stand-alone venture capital organization with over $140 million under management. ARCH Development Corporation continues as the licensing and new business development arm of the University of Chicago.

At ARCH we work with innovations from the University's divisions of

[1] This is an edited transcript of a slide presentation. Slides from Teri Willey's presentation are included at the end of the text, with callouts to the slides appearing in the text.

Biological Sciences as well as Physical and Social Sciences. We are working more and more in the "copyrightable" works area and with "content."

When ARCH was formed, Argonne did not have an office for technology licensing. Now Argonne has a group of competent licensing professionals. Accordingly, we work with them on a case-by-case basis, primarily when forming a company seems to be the best means to advance an innovation.

From 1986 until 1995, ARCH formed 18 companies, signed several licenses, and generated in excess of $20 million from licensing and equity returns (Slide 4). In 1994 and 1995, ARCH achieved two concurrent and critical milestones of breaking even and becoming cash flow positive. This allowed us to pay back the university the funds they provided in support of ARCH and to move forward as a self-sustaining organization. Much of this milestone was due to a "spike" in equity returns as a result of one company sale and one company initial public offering (IPO). The sale was that of a company called Everyday Learning. Everyday Learning is a company based on the copyrightable works for teaching K-12 math.

In the recent AUTM report, because of this spike we ranked in the top five for universities and even ranked ahead of MIT in terms of revenue from royalties and equity (Slide 5). It is fun to show this table for this reason, but important to point out that the next year or two will probably not be as spectacular, as we are not expecting any significant equity sales (spikes) again until 1999. Note that both these "exiting" companies were formed in 1988.

If you look at our returns and where they come from, in addition to the rare but celebrated equity spikes, we have very predictable and steady growth in our royalty returns from licensing agreements. These royalty returns are based on a portfolio of about 100 active license agreements. These license agreements are most often based on inventions disclosed six to eight years ago. Interestingly, about 50% of these royalty returns come from companies that ARCH started. I think this is very important. It is not unusual for the returns from equity to come prior to sales of product; hence, if we are successful in setting up robust companies, we will see a good royalty stream, in addition to a spike from equity.

ARCH has been a laboratory of sorts and, while it is easy to talk about the successes and where we are with regards to metrics, we continue to iterate and improve and hopefully learn from our mistakes (Slide 6). In 1986, when our board enthusiastically put forward this program for starting companies around University of Chicago technology, ARCH was very focused on start-ups. I believe this focused effort was carried out at the expense of licensing programs and perhaps industry-sponsored research collaborations. We have some nice cash-from-equity successes as a result, but also some missed opportunities and, hence, a need to restructure to balance licensing to existing companies, as well as creating our own licensees.

More and more research universities are licensing inventions to start-up companies and taking some equity as a consideration for the license. ARCH is unusual in that we take it one step further and sometimes create our own licensees (Slide 7). In doing this we provide what we call a "walk-around-round" to launch company projects, as well as provide part of the first seed round of funding. We have a strong relationship with our graduate school of business at the University of Chicago. This relationship has resulted in ARCH providing entrepreneurial experience to a number of business students (and physical and life science students as well).

We encourage an entrepreneurial culture. We have a Board of Directors, separate from the University of Chicago, which is very focused on entrepreneurial activities.

ARCH is self-supporting. That is, it doesn't cost the University of Chicago any money to have a technology transfer program. We cover all the patent expenses, the salaries, rent, and so forth, and when we have money in excess of expenses, as we do now, we return it to the university.

At any one time in our start-up company portfolio, we will have about a dozen projects (Slide 8). Usually, we have three new ones coming in and the rest at different stages of development and financing. The idea is to graduate about two projects a year. "Graduation" means they have support from an investor other than ARCH and have moved beyond the seed round.

As we receive invention ideas we evaluate them to determine whether or not we should invest in them (Slide 9). Then we decide whether to license to an existing company, license to a start-up company that somebody else forms, or form our own licensee.

We find start-up projects through our licensing activities (Slide 10). We also find them through our own start-up company activities. That is, a start-up company may need more than just the University of Chicago innovation to provide the necessary technology platform. Accordingly, our companies are often licensees of other universities or small companies. However, in order for us to use our investment funds it is necessary for us to have in the core, technology that originated at the University of Chicago or Argonne.

We encourage the use of Small Business Innovative Research (SBIR) funding (Slide 11). We find these funds useful in demonstrating proof of concept. Importantly, these funds are non-dilutive. At early stages of company formation we try to stay very lean. In addition to SBIR funds we may provide the walk-around-round I mentioned earlier. The walk-around-round is primarily out-of-pocket expenses for our "sweat equity" or "at-risk" CEOs (Slide 12). Usually our start-up managers are not paid a salary. They do the work for equity. That's one of the acid tests to decide whether or not a project is worthy of a start-up effort. If we can find a CEO who has started a company in the field before and who is willing to stick his or her neck out again, that is a good indicator.

We may also provide some funds to pay consulting fees. Sometimes we will hire experts to assist us with managing complex deals and move projects. We carry patent and other legal costs during the stage; however the start-up is obligated to eventually reimburse us for these costs.

In addition to our licensing and start-up divisions we have a small "virtual venture fund." This is a fund we use to buy preferred stock when we invest in the first seed round of financing (Slide 13). We often find it helpful to use these funds to provide matching funds to our state venture fund. Returns from the preferred shares acquired by ARCH (on behalf of the university) are used to replenish the fund, and anything in excess of $1 million dollars in the fund any calendar year is returned directly to the university. Likewise, returns from licensing are used to support the licensing program, and returns from equity taken as a result of formation are used to support the start-up division.

We like to keep the exit strategy flexible. We expect very few of our deals to go public. We plan for most of them to result in acquisition. If we have a successful exit (IPO or acquisition) we sell our stock. In the companies we form we will have stock from three sources: (1) equity as a result of formation (we start with 50% for ARCH/university, 25% reserved for management, and 25% held for the University scientists); (2) equity as a result of licensing (that is we may take 5% equity in consideration of the license instead of an up-front fee); and (3) equity as a result of investing in the seed round (Slide 14).

Another important point is that, when we form a company, we are creating a licensee (Slide 15). Hence, we enter into a license agreement with the company. The licensing agreement has standard terms for reimbursement of patent expenses, payment of royalties, milestone payments, and so forth. Being the owner of the company (the licensee) as well as the licensor does create a conflict. However, we believe it is a manageable one. One of the ways we manage it is to "live in a glass house." That is, as we do these transactions, we know that at the end of the day we have to be able to show that they are comparable to other transactions in which we license to a company that we do not hold equity in or that some other entity forms. It is an interesting situation to be in. It makes one very empathetic being on both sides of the table. Furthermore, we have to remember that we enjoy tax-exempt status, and we have these assets in intellectual property because of federal funding and, accordingly, we have to always act in the best interest of our constituents, the U.S. taxpayers.

The scientists stay involved as scientific advisors, sometimes chairing a scientific advisory board. This is formalized through consulting agreements and other standard transactions. They usually are not directors or employees of the company.

One last note on the start-up company activities is that our most critical resources are our sweat equity CEOs (Slide 16). They provide an acid test on whether or not this is a good project to get involved in. They also allow us to be in a situation where the scientist is not heavily involved in the management of the company.

Where do we find the sweat equity CEOs? First, we constantly churn our network. One of the things that we do not have at our disposal in Chicago is a pool of entrepreneurs of the sort one finds in Boston or San Francisco. In fact, one of the reasons that ARCH was formed was that there wasn't the infrastructure to do start-ups. So we churn our networks in the business community, the alumni, the business school, the entrepreneurial groups, the seed funds in the area, other venture capitalists, outsourcing groups that are placing executives leaving large companies, and other places. It's hard work.

One of the tools we use for finding entrepreneurial management is our Monday morning meeting. Every Monday morning from 9:00 to 11:00, we review our start-up projects and certain individuals are invited to attend. Many attending are potential CEOs or people that we would like to introduce to a project.

Now, I am going to talk a bit about the Association of University Technology Managers (AUTM) (Slide 17). Their activities are very much based on the Bayh-Dole Act, an excellent piece of legislation (Slide 18). AUTM is an organization of individual professionals. AUTM sponsors programs on licensing principles, marketing, and contract law, with a focus on public benefit (Slides 19 and 20).

The emerging issues that I think are most relevant right now are related to our continuing to improve our industry-university relationships (Slide 21). The longer that I am in this business, the more I realize that it comes down to people and it comes down to managing relationships and managing expectations.

When my kids ask me what I do for a living, I tell them that my job is to make sure that certain smart people play nice together. We all have divergent interests, and my job is to help everybody stay focused on where we have a common interest, so we can reach agreements and get this work done if it's worth doing (Slide 22).

We are working in a very complex playing field (Slide 23). The amount of litigation is increasing between universities and between university and industry partners regarding patent issues and contract issues. We are subject to more and more public scrutiny. There is a higher demand for our services. Yet the resources available to provide those services are not increasing in kind. We constantly receive conflicting directives from the different constituencies that we serve, and the complexity of deals is increasing. And our situation is going to become more and more complex.

This deal complexity issue is important to talk about, if for no other reason than to acknowledge and perhaps to accept it (Slide 24). I don't think we should try to fool ourselves into thinking that things are going to get simpler and more streamlined. They are not. They are going to get more and more complex. The sooner we accept that and not just tolerate it, but embrace it, the faster and better we can move forward.

I worked on a project a couple of years ago in which a broad platform technology was originally licensed before its breadth was known to a large pharmaceutical company. The company had decided not to develop it because of organizational changes. Our due diligence terms were not strong enough to take the technology back and terminate the agreement. So we had to appeal to the company to give us the rights back so that we could ensure that the technology would be commercialized. After a long process, the company did the right thing and granted the rights back to us.

By this point, we had over 30 inventors from 4 different institutions, including one for-profit company and a hospital new to patents and licensing. We chose to sort out the rights among these individuals and organizations. None of them fell under a single patent policy regarding return of income. The result was that the technology was licensed to three different for-profit companies for specific fields of use for development. One of them just embarked on its first clinical trials for the product this month. Most fields were licensed to a core technology company, a start-up company that would develop the material and distribute it and manage the licensing of the remaining rights. The technology is the basis of over a million dollars a year in sponsored research, some of which supports graduate and post-doc positions.

The barriers seemed insurmountable, but the deal happened, and the reason that it happened is that we accepted the complexity and put our efforts into helping the divergent groups to focus on where they had a common interest.

There are issues on which industry and universities have different views (Slides 25, 26, and 27). At the same time we have some of the most creative minds around. Accordingly, we know what we need to focus on what we need to do and close deals. While others are posturing and complaining, lets' go out and close some deals.

One of the things that I worry about is that most university programs are not well funded to carry out this work as the demand for it continues to increase (Slide 28). One of the reasons that they do not have the funds may be due to how revenues are shared with the technology transfer program. Programs probably need to keep a larger share of returns to support, grow, and improve their efforts.

One important means to manage this type of work is outsourcing. That is, to bring people in on retainer and give them a piece of the action in order to have additional deal help in some very specific fields. This can be very effective, with the right people. It allows the program to grow when needed, without committing to the full burdened price of staff.

Another ongoing experiment is performance-based compensation. A unique aspect of ARCH is that all the professionals in the ARCH organization participate in a bonus pool where a share of the returns from licensing and cash from equity go into a bonus pool. This is distributed based on the overall performance of the organization, which includes financial performance and also incorporates goals that the university wants us to focus on, such as faculty service, and facilitating and bringing in industry-sponsored research. Those are difficult things to measure, but including them sends the message that even though we are a stand-alone organization, we have to act in a way that is consistent with the needs and the mission of the university.

One of the interesting things we are working on with our compensation program is the question of "what happens if an employee follows an incentive program blindly?" If making the wrong deal will benefit them, should they go ahead and do it anyway? A good incentive program does not take the place of having the right people who do things for the right reasons. Clearly, no one needs an employee who is going to blindly follow an incentive program, even though he or she knows it will result in a wrong decision. My employees know that they make their decisions based on much more than the incentive plan or they don't stay in our organization.

One of the main things that makes this work manageable is concentrating on end points and what is to be accomplished, remembering that we are trying to commercialize these research results and that we are trying to get a fair return in the process.

One of the other issues that we all grapple with is this: if our mission is public benefit, then why are we so focused on financial returns? I think the simple reason is that it takes returns to carry out this work. So, if you have a chance to obtain a fair return, one that reflects your contribution to a profit margin somewhere down the road, then obtain it and use it to perpetuate the process (Slide 29). As long as it is a fair return, it would be irresponsible to forgo it.

Another critical factor in the field is how to attract and keep good people engaged in this work (Slide 30). One reason that academic organizations have liability in areas such as commingling of funds or licensing technology to more than one company is that we do not have enough continuity with the professionals in this area. We have to come up with ways to attract and keep the good people. We have to have flexibility with staffing. We have to be able to take more of our returns and invest them into making sure the office is staffed and stays staffed.

It has been reported that sponsored research at universities yields four times as many patent applications per dollar as corporate research funds spent internally (Slides 31 and 32). This is an interesting figure. This does not mean that those patents all turn out to be good or result in products or public benefit, but it does provide a metric. We can probably imagine why that happens. It is because the work in the university laboratories is not done with just those dollars. Those sponsored research funds are very highly leveraged. It may also be the case, because faculty members have incentives to participate in the patenting and licensing process.

When we look at what appears to be terrific performance in university technology transfer operations, does it mean we can be complacent? Does it mean that we are doing okay, and that we can continue to work with our current models? Of course, the answer is no, because there is a lot of room for improvement. A lot of the success is in the life science area. The models that work in life science probably do not work in some of the other fields. So we have to continue to examine these things in a way that is focused on the principle of ensuring that the research results are commercialized.

We have to continue to think creatively about solutions (Slide 33). I think it is very important to listen to criticisms and concerns, regardless of where they come from, and to constantly reexamine our approaches (Slide 34).

The paradox in the university world is that we are not-for-profits living in a for-profit world (Slide 35). If we are good at what we do, we will understand the university well enough to assist the companies and the companies well enough to assist the university. We act at a critical interface.

This is not just a field of law, science, and business, but maybe it is a field of human endeavor (and success is based on understanding human behavior) (Slide 36).

One asset that we have is our ability to work together. Through my 10-plus years in AUTM one of the robust aspects of the group is that it is 60% "affiliates." When I started, there were about 100 members, and now there are 1,800 members, and almost 900 of them are industry members. So, as we come up with ways to put together industry-sponsored research agreements and licenses, we are doing it together. Also, we have people from universities who are moving to industry and people from industry who are taking university jobs. So we have more and more professionals with experience on both sides of the fence. They understand each other. They can empathize, and it helps us all do a better job.

Slide 1: Overview

- A little about ARCH
- A little about AUTM
- What's important
- What seems to work
- Some evidence that it does

Slide 2: A Little About ARCH

- ARCH Development Corporation is a not-for-profit wholly owned subsidiary of the University of Chicago.
- It was formed in 1986 to license UC and ANL inventions to existing companies and with a emphasis on starting new companies.
- ARCH Development Corporation and Arch Venture Partners are two district organizations with a common origin

Slide 3: About UC and ANL

- University of Chicago:
  - Biological/Medical Sciences--$100M Research Funding (700 Faculty)
  - Physical Sciences--$70M Research Funding (170 Faculty)
- Argonne National Labs:
  - $500M Budget--Emphasis Environmental, Energy, Physics, Chemistry, Biology, CS

Slide 4: ARCH through 1995

- Started 20 companies ... 3 successfully exited, 6 near-term exits, 7 tanked, 4 early-stage.
- Executed ~90 licenses
- $4M in equity proceeds and royalties distributed to inventors
- Repaid $5M loan from University
- $4M net income on gross revenue of $18M

Slide 5: Direct Returns from Technology Transfer - 1996 AUTM Survey

- 1. U. California System $63
- 2. Stanford $44
- 3. Columbia $41
- 4. Michigan State $17
- 5. U. Wisconsin-Madison $13
- **6. U. Chicago (ARCH) $12**
- 7. U. Florida $11
- 8. MIT $10

Slide 6: A Laboratory of Sorts...

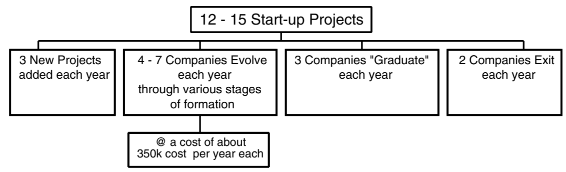
Where we may have learned much more from our mistakes than our successes.

Slide 7: What May Set ARCH Apart

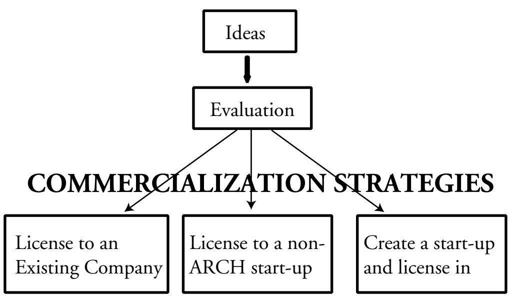
- Licensing **and** start-up business emphasis
- "Walk-Around-Round" funds
- Seed capital availability
- Ties to University of Chicago GSB
- Entrepreneurial culture and focus of BOD
- Self supporting
- Compensation System

Slide 8: The ARCH Company Start-up Portfolio

Estimated Composition and Turn Over Required to Meet Financial Goals



Slide 9: ARCH Process Flow Chart



Slide 10: New projects are identified via the prospecting efforts of:

- our licensing business:
  - at the UC
  - at Argonne
- our start-ups:
  - to identify technology that compliments our competencies at other top research institutions
- our consulting network:
  - to identify hot emerging technologies/markets

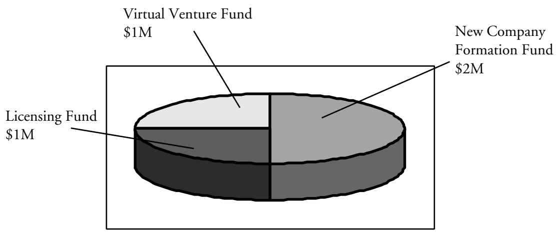
Slide 11: Some Characteristics of our Start-ups

- Light initial capitalization
- Senior management compensated w/stock
- Government co-funded IDFA and SBIR
- Outsourcing some R&D
- Exit strategy flexible but we like buy out
- Licenses into company include royalties, milestones

Slide 12: "Walk-Around-Round" via ARCH may include all or part of:

- Out of pocket expenses of "S.E. CEO's"
- Consulting Fees
- Formation Legal Expenses
- Rent
- Carry on patent expenses
  - about 30,000/year/company for 2-3 years and does not include cost of ARCH personnel/indirect costs

Slide 13: ARCH Capitalization



- Bonuses distributed only if Funds maintain minimum balances
- Excess returns distributed to U of C and Argonne

Slide 14: Sources of Equity

- As part of the consideration in licensing to an existing company or start-up formed by a third party.
- As a consequence of ARCH forming the company.

Slide 15: ARCH Companies

- When ARCH forms a company . . . it is creating a licensee.
- In this case we take equity for forming the company . . . not as a consideration for the license.

Slide 16: The Critical Resource . . .

The ARCH Start-up Co . . .

CEO

AUTM

Slide 17: AUTM

A nonprofit professional organization devoted to continuing education to its members, as well as policy makers, in a manner that will enhance the timely commercialization of research results from academic laboratories.

Slide 18: The Bayh-Dole Act

A reliance on non-profit research institutions as major strategic partners in creation of new technology, and most importantly, bringing the research results forward to the public in a meaningful way!

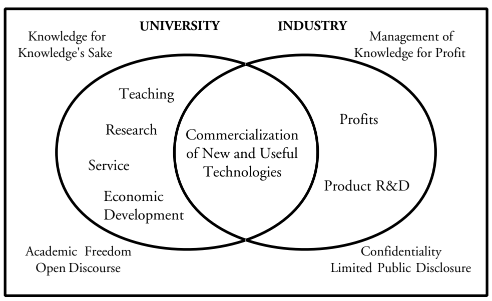
Slide 19: Technology Management with Focus

On Public Benefit

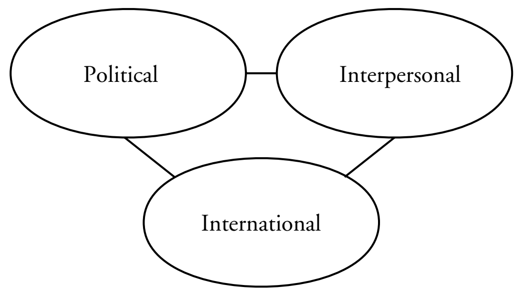
Slide 20: **(Public) Benefit** means different things to different people (constituents)

- Government policy makers
- Government research sponsors
- Industry research collaborators
- Local and regional stakeholders
- University management
- Faculty researchers

Slide 21: University/Industry Relationship



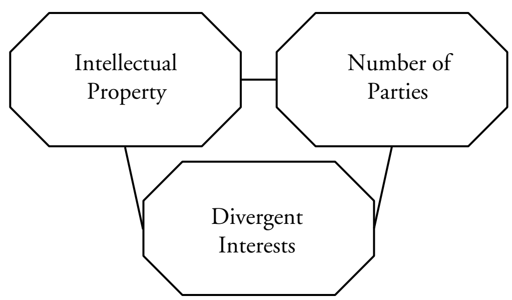
Slide 22: The Demands:



Slide 23: Behind these general demands...

- Litigation
- Public Scrutiny
- Legislative Activity
- Conflicting Directives
- Deal Complexity
- Market Dynamics
- Scarce Resources
- Increased Demand

Slide 24: Deal Complexity:



Slide 25: Industry - University Issues:

- Ownership and management of I.P. rights
- Commercialization of research tools
- Dissemination of information/publication
- Continuity of research programs
- Control of direction of research programs
- Conflicts of interest and commitment

Slide 26: And More Industry - University Issues

- Costs of transactions at the interface
- Co-mingling of funds
- Future rights
- Background rights
- Indemnification and warranties

Slide 27: The Compete vs. Cooperate Tension

Slide 28: Demand for ⇧ Services Resources ⇩

- Operations
- Program financial policies
- Out-sourcing
- Performance-based compensation

Slide 29: It takes resources...

To serve our constituencies well we must capture a fair return from innovations created with public funds.

it's not just our responsibility to do so . . .

it's irresponsible not to.

Slide 30: some csf's in this field...

- Ability to attract and keep the good ones
- Capturing return back in to the program
- Flexibility with staffing
- Gap funding
- Staying on the front lines
- Cooperative programs
- Alignment of incentives

Slide 31:

Sponsored research in universities yields 4 times as many patent applications per dollar of corporate research.

Haber E., "Industry and the University," *Nature Biotechnology* 14:1996; 441-442

Slide 32: $10 Million Invested

In University Alliances

22.6 Patents

In Fortune 500 Companies' internal research

13.1 Patents

Haber E., "Industry and the University," *Nature Biotechnology* 14:1996; 441-442

Slide 33: Innovation in more than the laboratory

Solutions through strong relationships, optimism and creative problem solving

Slide 34: Constantly question

Consider the criticism and continue to revisit assumptions

Slide 35: Embrace ambiguity and complexity

Believe in the paradox

Slide 36: How we work

It's a field of human endeavor and human behavior

How we carry out our business and treat one another will set the tone for these important relationships

Appendix C

University-Industry Collaborations Discussed at the Workshop

Partnership/ Program	Type of Collaboration	Key Points
Amgen's collaboration with Sloan-Kettering, Max-Planck Institute, MIT, and other academic institutions	Ranges from sponsored research and student support to faculty consulting and focused collaboration on clinical trials.	• Valuing contributions is an issue: universities are trying to capture greater value but may be unrealistic. • On some issues (delay of publication) there are standard practices that work; sometimes companies ask for more time to patent than they really need. • Other issues include preventing conflicts of interest (in clinical trials) and restrictions placed on institutions by some non-profit sponsors.
Carnegie Mellon University's collaboration with industry, including the Data Storage Systems Center, collaboration with Caterpillar, and university-based start-ups	Includes an Engineering Research Center, master agreements, and start-ups in which the university owns equity.	• More inexperienced foreign-based companies are entering collaborations. • More master agreements are required, with more difficult and complex negotiations. • The management structure for master agreements is important. • Complex interactions must be coordinated among university-managed incubators, tech transfer to start-ups, university equity ownership, and faculty entrepreneurs. • Insights from collaboration do make it into the curriculum, often more quickly than people realize.
Biotechnology Research and Development Center (national consortium)	For-profit corporation with equity ownership by industry members. Commercializes Department of Agriculture-sponsored research	• Focus has gradually moved from discovery research to demonstration of feasibility on campus. • Will give universities greater equity if they reduce indirect rates.

Partnership/ Program	Type of Collaboration	Key Points
Rensselaer Polytechnic Institute Incubator Program	University owns three buildings housing a number of start-ups, some coming out of the university, some spun off from larger companies.	• One of the oldest university-run incubators; high survival rate but no huge successes yet. • Networking and collaboration are essential; alumni are potential "angel" investors. • Emerging trend is to link university endowment or public venture capital firms with the incubator.
Optoelectronics Computing Systems Center	Engineering Research Center (ERC).	• ERC program was intended to create a new kind of student. This is happening, but more needs to be done to move insights into the curriculum. • Some companies have caused management problems by pulling out funding at short notice or funding at lower than critical mass and demanding background rights. • A general issue is that ERCs and Science and Technology Centers may promise more than can be delivered and become disconnected from the university. There are examples where the center played a positive role in breaking down disciplinary and other barriers on campus. • This ERC has launched a number of start-up companies, helping to create a regional technology focus.
University of Utah, various collaborative projects	Start-ups generated by university research, sponsored research.	• Rules are needed to protect the institution, faculty, and students. • In one case a company sponsors research by a faculty member who holds equity in the company. The university holds equity as well and has a broad licensing agreement. This sort of relationship can be difficult to manage. • Can negotiate non-disclosure for longer than 60-90 days if no students are involved and non-tenured faculty members sign an agreement that they understand. • Some private foundations are now imposing onerous intellectual property right provisions. • Indirect costs simply cannot be negotiated away. Need to pay them somehow. Sometimes it is a matter of saying no to faculty members who insist that waiving them is needed to gain industry support. • Demand for reach-through rights to inventions developed through use of university research materials can be a problem. The university wants the package to be of maximum use, but difficulties arise when industry wants a royalty-free license to the work of many individuals.

Partnership/ Program	Type of Collaboration	Key Points
Real-Time Innovations `	Start-up based on software developed at Stanford; used in robotics, space shuttle. Currently Stanford is a Real-Time Innovations subcontractor on an Advanced Technology Program contract.	• Company provides a platform for Stanford-developed tools to become more widely used. • Patents on software do not generate much revenue; value is mainly defensive. • Success based on long-term relationships, trust, understanding.
National Textile Center/University Research Consortium	Government-supported industry consortium that funds university research.	• Has brought together companies representing the entire value chain: Dow Chemical through Wal-Mart. • Centered on a highly competitive global industry that does not receive much federal support. • Encourages universities to focus on industry problems.
Akzo Corporate Research, collaborations with academia	Various forms of collaboration, including a project to remove toxic chromium from products involving Akzo, NASA labs, Drexel University, Polytechnic University, and Ohio State University.	• Chemical industry is focusing internal research on definite product goals; speculative work is done only in partnerships. • Key factors are trust, good intellectual property provisions, and sufficient funding. • University productivity goes down in proportion to time spent preparing the next proposal. Universities need a consistent liaison in the company. • Funding must be committed for three years—the length of a dissertation. • Companies see the benefit in attracting graduates as employees. • Companies will go to overseas universities when conditions are favorable.
ARCH Development Corporation	Non-profit subsidiary of the University of Chicago aimed at commercializing inventions from the university and Argonne National Laboratory.	• To date, 20 companies have been launched. Income rising gradually with occasional spikes. Now self-supporting. • Finding CEOs for the start-ups is an issue. • Should tech transfer be handled in-house, by a non-profit subsidiary, or by a for-profit contractor? Some functions may need to be managed close to home.
Walt Disney Imagineering	Hiring students, engaging in some sponsored research.	• Interdisciplinary skill sets are increasingly important to the entertainment industry (e.g., computers and art). • Better to walk away from a negotiation immediately rather than waste time when the chemistry is not right or trust is lacking.

Appendix D

Workshop Agenda

THE GOVERNMENT-UNIVERSITY-INDUSTRY
RESEARCH ROUNDTABLE
in cooperation with
THE COMMITTEE ON SCIENCE, ENGINEERING,
AND PUBLIC POLICY
presents
Overcoming Barriers To Collaborative Research: A Workshop
March 23-24, 1998
National Academy of Sciences & National Academy of Engineering
Beckman Center
Irvine, California

Monday March 23, 1998

8:30 Welcome and Statement of Purpose (Lecture Room)

Project Co-Chairs: Gerald Dinneen
Honeywell, Inc. (retired)
Jean Bonney
Director, Education Research/Business
Digital Equipment Corporation

9:00 Opening Address - "How Do We Manage: Tools, Metrics, and Techniques"

Gene Slowinski
Director of Strategic Alliance Research
Graduate School of Management
Rutgers University

9:45 Perspectives from the Sectors: "The Value of Partnering"

Industry: Daniel Vapnek, formerly Senior Vice-President for Research, Amgen

Academe: Paul Christiano, Provost, Carnegie Mellon University

11:00 MODULE ONE: "Innovative Approaches to Managing the Intersection of Interests in Collaborative Research Relationships"

The challenge for this section of the agenda is to identify and to feature real cases of collaboration that draw focus to the thorny issues that plague partnerships, and that reveal successful approaches to managing those trouble spots. The cases have been selected to illustrate several very different structural approaches to forming partnerships, alliances, or other types of collaborative arrangements.

Case Study I: Consortia

Grant Brewen, CEO, Biotech Research and Development Consortium (BRDC), Peoria, Ill.

11:30 Q&A, Group Discussion

12:00 Lunch Buffet

1:30 Case Study II: Incubator

Glenn Doell, Director, Incubator Program, Rensselaer Polytechnic Institute and Vice-Chairman, National Business Incubation Association

Case Study III: Government-funded Research Center

Kristina Johnson, Director, Optoelectronic Computing Systems Center, University of Colorado, Boulder

3:00 Q&A, Group Discussion

4:00 Breakout Discussions

<u>Tuesday March 24, 1998</u>

8:30 MODULE TWO: "Proprietary Impediments to Research Partnerships—Intellectual Property, Patenting, Royalty Rights, and Reach-Through Provisions"

While formulaic solutions to these problems do not exist, templates to address each of these issues are relatively plentiful. In this session, speakers will lead discussion of prototypes they and members of the audience have used in negotiating and managing research partnerships with outside parties, highlighting the shortfalls of each; they will discuss the informal or ad hoc solutions they have discovered through experience; and they will direct discussion to options for improved partnering. Speakers and cases have been selected to illuminate differences encountered across disciplines (e.g., biomedical vs. info tech) and across types of institutions.

Opening Remarks

Stephen Atkinson, Director of Licensing and Technology Management, OraVax

9:30 Sectoral Variants:

<u>Prototype I: Biomedical Research</u>

Richard Koehn, Vice-President for Research, University of Utah

10:00 Q&A, Group Discussion

10:45 <u>Prototype II: Information Technology</u>

Stan Schneider, President, Real-Time Innovations, Inc.

<u>Prototype III: Advanced Manufacturing</u>

Joe Cunning, Executive Director, National Textile Center/University Research Consortium

11:45 Q&A, Group Discussion

12:15 Lunch Buffet (Refectory)

1:30 Prototype IV: Specialty Chemicals

Francis Via, Director of Contract Research, Akzo Corporate Research

Prototype V: Academic

Teri Willey, Vice-President, ARCH Development Corporation

2:30 Q&A, Group Discussion

3:00 BREAK

3:15 Working Sessions: "What Will We Take Home?"

Moderated by Jean Bonney and Gerald Dinneen, Project Co-Chairs

4:30 Closing Commentary: Visions for the Future

Eric Haseltine, Vice-President & Chief Scientist for Research & Development, Walt Disney Imagineering, Inc.

5:00 Adjourn

Appendix E

Workshop Participants

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY

Overcoming Barriers to Collaborative Research: A Workshop

March 23-24, 1998

National Academy of Sciences & National Academy of Engineering

Beckman Center
Irvine, California

Alice Agogino
Professor
Mechanical Engineering
University of California

Richard Alkire
Vice-Chancellor for Research
University of Illinois at Urbana-Champaign

Susan Allen
Vice-President for Research
Florida State University

Thomas Arrison
Staff Officer
National Research Council

Stephen Atkinson
Director
Licensing and Technology Management
OraVax, Inc.

Gary Bachula
Under Secretary
Technology Administration
U.S. Department of Commerce

Jean Bonney
Director
Education/Research Business
Digital Equipment Corporation

Jeffrey Brancato
Directorate for Mathematics & Physical Sciences
National Science Foundation

J. Grant Brewen
Chief Executive Officer
Biotech Research and Development Consortium

John B. Bush, Jr.
Vice-President
The Gillette Company

Kelly H. Carnes
Deputy Assistant Secretary
Technology Administration
U.S. Department of Commerce

Jean-Lou Chameau
Dean of Engineering
Georgia Institute of Technology

Paul Christiano
Provost
Carnegie Mellon University

Joe Cunning
Executive Director
National Textile Center
University Research Consortium

Gerald Dinneen
Honeywell, Inc. (retired)

Glenn Doell
Director
Incubator Program
Rensselaer Polytechnic Institute

Raymond Fornes
Associate Dean for Research
College of Physical and Mathematical Sciences
North Carolina State University

Edward Furtek
Associate Vice-Chancellor
Science & Technology Policy and Projects
University of California, San Diego

Susan Gates
Associate Economist
RAND Corporation

Denis Gray
Psychology Department
North Carolina State University

Eric Haseltine
Vice-President & Chief Scientist for Research and Development
Walt Disney Imagineering

Barrie Hesp
Vice-President
Technology Investments
Central Research Division
Pfizer, Inc.

David Hodges
Professor
Electrical Engineering & Computer Sciences
University of California, Berkeley

Susanne Huttner
Director
Industry-University Cooperative Research Program
University of California

Kristina Johnson
Director
Optoelectronic Computing Systems Center
University of Colorado

Joshua Kalkstein
Central Research Division
Pfizer, Inc.

Richard Koehn
Vice-President, Research
University of Utah

Wanda London
Research Associate
Government-University-Industry Research Roundtable
National Academy of Sciences

Christine Maziar
Executive Vice-President & Provost
Office of the Executive Vice-Provost
The University of Texas, Austin

Virginia Meade
Research Program Manager
Intel Corporation

James Merz
Vice-President
Graduate Studies & Research
University of Notre Dame

Thomas Moss
Executive Director
Government-University-Industry Research Roundtable
National Academy of Sciences

David Mowery
Professor
Haas School of Business
University of California, Berkeley

Kumar Patel
Vice-Chancellor
University of California, Los Angeles

Luis Proenza
Vice-President for Research
Dean of the Graduate School
Purdue University

Allison Rosenberg
Associate Executive Director
Government-University-Industry Research Roundtable
National Academy of Sciences

Stan Schneider
President
Real-Time Innovations, Inc

Robert N. Shelton
Vice Provost
Office of Research
University of California

Eugene Slowinski
Director
Strategic Alliance Studies
Graduate School of Management
Rutgers University

Elizabeth Starbuck
President
Calyx, Inc.

Jack Tribble
Senior Patent Counsel
Merck & Co., Inc.

Daniel Vapnek
Senior Consultant
Research and Technology
Amgen, Inc.

Francis Via
Director
Contract Research
Akzo Corporate Research, Inc.

Lydia Villa-Komaroff
Vice-President for Research & Graduate Studies
Northwestern University

Andrew Viterbi
Vice-Chairman
Qualcomm, Inc.

Teri Willey
Vice-President
ARCH Development Corporation
University of Chicago

Carolyn Woo
Dean
College of Business Administration
University of Notre Dame

John Yost
Research & Development Coordinator
University Research Office
University of Idaho

Endnotes

1. Industrial Research Institute (IRI), Government-University-Industry Research Roundtable (GUIRR), Council on Competitiveness (CoC). *Industry-University Research Collaborations: Report of a Workshop*. Washington, D.C.: National Academy Press, 1996.

2. J. D. Roessner. University-industry collaborations: Choose the right metric. *Science's Next Wave* June 1996.

3. Government-University-Industry Research Roundtable and Academy Industry Program. *New Alliances and Partnerships in American Science and Engineering*. Washington, D.C.: National Academy Press, 1986. Government-University-Industry Research Roundtable and the Industrial Research Institute. *Industrial Perspectives on Innovation and Interactions with Universities—Summary of Interviews with Senior Industry Officials*. Washington, D.C.: National Academy Press, 1991. Government-University-Industry Research Roundtable. *Intellectual Property Rights in Industry-Sponsored University Research—A Guide to Alternatives for Research Agreements*. Washington, D.C.: National Academy Press, 1993. Government-University-Industry Research Roundtable and the Industrial Research Institute. *Simplified and Standardized Model Agreements for University-Industry Cooperative Research*. Washington, D.C.: National Academy Press, 1988.

4. N. Rosenberg and R. R. Nelson. American universities and technical advance in industry. *Research Policy* 23(1994): 323-348.

5. Several of the examples discussed at the workshop, such as the National Textile Center and the University Research Consortium, have this focus.

6. D. C. Mowery. Collaborative R&D: How effective is it?" *Issues in Science and Technology*. Fall 1998. U.S. General Accounting Office. *Technology Transfer: Administration of the Bayh-Dole Act by Research Universities*, GAO/RCED-98-126, Washington, D.C., 1998.

7. D. E. Massing, ed. *AUTM Licensing Survey: FY 1996*. Association of University Technology Managers, Inc., 1997. For example, in 1996, 2,095 patents were issued to universities (up 14% from 1995), 248 start-up companies were formed (up 11% from 1995), and licensing income reached $591.7 million (up 19.6%).

8. See Note 1.

9. G. Blumenstyk. Turning off spin-offs; Bucking a trend, University of Arizona ends direct commercializing of faculty research. *Chronicle of Higher Education*, July 21, 1995, p. A33.