Chapter 5
Industrial Collaboration and Technology Transfer

CONTENTS

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5.1 OVERVIEW

A central motive of the Engineering Research Centers (ERC) program is to form partnerships between academia and industry in systems-oriented research areas that are critical to the Nation's economic strength. Each ERC collaborates with industry from the early stages of its vision creation and strategic planning, and collaboration extends to technology development and application. By thus expanding and accelerating technology transfer and eventual commercial use, this approach bridges the traditional technology transfer gap between the single university investigator and industrial adopters of academic research results.

The ERCs are distinctive among NSF research centers in this embracing of industry throughout the entire cycle of technology creation, development, and implementation. Each ERC team envisages and plans technology development with its industrial partners from the outset. Each center's strategic plan, developed with industrial members, helps identify areas for joint projects and experimental testbeds for validating research results in practical applications. NSF holds ERCs responsible for tracking their research results through commercial implementation.

ERCs must build large research programs with considerable financial support from industry. While some support may be in the form of contractual agreements with deliverables, in many centers an equivalent or greater sum consists of unrestricted industrial grants to the center. Special emphasis is often placed on attracting small and medium-sized companies to ERCs because of their more rapid acceptance of new technologies and rapid growth potential. ERCs are not discouraged from involving foreign-owned companies as long as reciprocity of information, expertise, and people is emphasized (see Section 5.3.1.5). In 1999-2000, 10% of ERCs' industrial members were foreign-owned companies.

According to data gathered by individual centers and by NSF, ERCs have been very successful in attracting and providing benefits to industry. In 1999-2000 there were 439 industrial memberships in 18 centers, or an average of 24 companies per center. The total number of companies involved was 326, since many companies are members of two or more ERCs. Of these companies, 25% were small businesses, 10% medium-sized, and 65% large. Equally impressive is the large number of technologies that have been invented by ERCs and implemented by their industrial partners. For example, as of fall 2000, a total of 347 patents had been awarded to 30 ERCs, 1,422 software licenses had been issued to companies, and 68 companies had been formed as spin-offs of ERC research. In addition, hundreds of discrete innovations had made their way into use in industry.

While all ERCs are expected to plan, create, validate, and transfer new technologies, some of these activities inevitably receive greater emphasis at different stages in a center's life cycle. New "start-up" centers (years 1-3) necessarily focus on strategic planning with industrial members, attracting new members to their efforts, and developing forums for interaction. Mid-term centers (years 4-7) must focus on demonstrating successful industrial collaboration and technology transfer results, promising more to come beyond the sixth-year review. Mature centers (years 8-10/11[1]) are putting new technologies into play while attracting new companies and finding new ways of teaming with industry without NSF support, including generating industrial endowments. Successful centers engage in long-term planning jointly with industrial members beginning in the early stages.

Experience shows that the enthusiasm and appeal of a start-up center is very effective in attracting industry involvement; but as centers mature, industrial collaboration requires more work, as sponsors become more demanding. On the other hand, age confers the advantages of experience and credibility. In the early stages, centers need to set modest membership fees, focus research on knowledge and technology development, and use industry as a partner in identifying problems. In later stages, centers may shift their base to large contracts with specific companies; research then should include a focus on applications and field-scale development based on the knowledge and technology developed, while maintaining a base of new and exploratory work.

Another way of viewing the center's life cycle is to consider that, in the first few years, NSF acts as a venture capitalist, funding a build-up of infrastructure and providing substantial leverage to industrial support. By year 6, the center has "gone public," establishing a certain amount of credibility with regard to its benefits to industry, and begins to face a new set of challenges. With the infrastructure in place, the center matures, and the issue of delivery becomes preeminent.

Industrial collaboration with ERCs extends beyond the development and transfer of technology. Industrial members become involved not only in strategic planning and collaborative research, but also in many educational activities. Industrial members give practical experience to ERC faculty and students by hosting faculty sabbaticals, student internships, and on-site ERC seminars. Members also participate at the center in hands-on courses, seminars, and co-advising graduate students.

Industrial involvement in the early stages of technology planning and development provides substantial payoffs when ERC students graduate. Member companies employ a large fraction of ERC graduates. Many of the hiring companies have noted that ERC graduates, by virtue of their systems-oriented training, are more skilled at technological innovation and product/process development than their non-ERC counterparts. They also are capable of integrating knowledge across disciplines, working in teams, understanding industrial needs, and addressing problems from an engineering systems perspective. Industrial sponsors typically comment that ERC students "land on their feet running" and

[1] ERCs established between 1985 and 1997 have 11-year terms of support by NSF; with the Class of 1998, this term was reduced to 10 years.

“do not require the usual 12 to 18 months to come up to speed.” Many ERCs and their industrial members agree that students are the best and most lasting form of technology transfer. (See Section 5.5.1.3 for a more detailed discussion of the job performance of ERC graduates.)

The ERCs' relationships with companies are experiments. Each one is unique, depending on the nature of the research undertaking, the scope and type of the industries involved, and the strategic direction of the center. Within this diversity there are common issues, which each center must resolve to create a functioning partnership with industry. The objective of an ERC should be to establish a very broad industrial constituency. Emphasis on the dollar amounts of support should be balanced by a focus on the intellectual and economic potential of a collaborative effort.

Ultimately, the ERCs are testbeds for broader cultural change in university-industry collaborative research. They are pioneering new ways of bringing research results to market, breaking down many traditional barriers that have hindered cooperation between universities and industry. Every lesson they learn makes it easier for those who follow to work together productively, as the working partnership of university administrations and faculties with corporate researchers develops. This is perhaps even more true of the centers that have graduated from NSF support, since those centers operate without federal subsidies and therefore must justify their benefits to both their host universities and their industrial members.

This chapter discusses some of the most effective practices that existing ERCs have learned to use in conducting industrial affiliates programs. It addresses issues such as establishing a partnership with industry, building an industrial constituency, the benefits and difficulties of industrial interaction, and the role that the NSF plays in this involvement. Case studies are used to illustrate some effective approaches. At the end of the chapter (Section 5.7) is a summary of the main lessons that have been learned; most of the sections also have a listing of specific lessons learned.

5.2 ESTABLISHING AN INDUSTRIAL AFFILIATES PROGRAM

5.2.1 Start-up Systems Development

A critical start-up activity in any center is to establish the vision and infrastructure that are required for an effective industrial collaboration and technology transfer program, including systems for tracking interactions with industry. The Director and senior leadership of the center typically form the vision and strategic plan for industrial interaction during the center's proposal development process. The infrastructure required to effect this vision and strategic plan must be developed with post-NSF survival in mind. One ERC had existed as a University/Industry Cooperative Research Center before becoming an ERC and had already established the basic foundation for their industrial collaboration, but found they had to adapt that model to the more strategic, systems-oriented ERC approach. Other new centers have surveyed existing ERCs during their initial development phases, to benchmark the strategic plans and infrastructure that were effective for the existing centers.

In the months after the formation of a new center, it is important to work with the university and its technology transfer office to establish internal support and work out an ERC membership agreement for the program. NSF requires each ERC to develop its own generic membership agreement, governing the participation of industrial and practitioner members and specifying the forms of industrial cash and in-kind contributions that constitute membership in the center. Following subsections of 5.2.1 address these issues. See Attachment A for specific NSF industrial membership requirements. In multi-institutional ERCs, where university/industry research centers may already exist, it is essential to examine and compare the existing membership structures, fees, and terms and conditions and involve all key personnel at the universities from the start in drafting the new ERC agreement. Support for the ERC is generally high immediately after the award of the cooperative agreement, and the climate for negotiating long-term university support is good. Some centers have negotiated return of overhead from grants received by faculty doing center-related research. In most universities the return of intellectual property revenue is divided according to a certain formula that includes the inventor, the university, the originating unit (the ERC), and other parties.

An important component of the strategic plan for industrial interaction is a clearly defined marketing strategy for recruiting industrial sponsors. Some of the techniques that ERCs use are discussed in Section 5.3.1.2. A well-developed marketing strategy typically includes an analysis of the industry sectors affected by the center’s research and of the value drivers that industrial sponsors will find attractive in a research and technology transfer relationship. The marketing plan includes financial and technology transfer goals, specific actions and timelines needed to reach those goals, and a budget for the Industrial Affiliates Program. This plan includes strategies not only for recruiting new members, but also for retaining existing ones, through customer service activities such as communications on center research activities and results, faculty interactions with sponsor companies, and regular visits to sponsors’ sites.

Advertising and "cold calls" to potential sponsors usually are not successful. Centers should instead target specific companies based on their involvement in the particular industry, their interactions with other sponsors, and their degree of involvement in technology development. The use of current industrial partners to identify leads is particularly effective in identifying potential new members. As in many business endeavors, perseverance is rewarded in recruiting sponsors. Strong and continuous follow-up with several people in the organization, often involving visits to the center and to the company, is usually required after the initial contact. For a new ERC without a track record, it is a good idea to market the center's program and vision. This approach can be particularly effective with companies that have been involved with other ERCs.

As in any customer-oriented enterprise, it is important to develop systems for tracking interactions with companies and assessing the effectiveness of the industrial collaboration and technology transfer; ERCs and NSF regard this capability as vital to any center's success. A customized database or commercially available contact tracking software package (such as Act! or Gold Mine) is a necessary tool. Most centers find it useful to maintain a contact log, to augment memory and to provide reminders on follow-up action items. In planning such a system, it is important to consider who will use or access it, how it will be backed up, and what features are important. At minimum, a center needs a complete company mailing list and a procedure for keeping it current. Security issues may arise if companies require that the list be used for center activities only (a reasonable request). In designing the system, one might also plan for the impromptu reports that will be needed, such as lists of currently active member companies or current fiscal information. NSF's database and reporting requirements call for accurate data on company membership, support, and other forms of involvement, which must be validated by the university's office of sponsored research. Section 5.3.3.5 discusses program assessment metrics.

As explained in more detail in Section 5.2.5, each ERC has a staff member who is responsible for establishing and maintaining liaison between the center and its industrial sponsors. Other commonalties, discussed in this section and elsewhere in this chapter, are the establishment of membership levels, contractual agreements, fees and benefits; intellectual property arrangements with the university; and reporting and communication mechanisms.

In a multi-institutional ERC, marketing, recruitment, and retention plans must reflect not only the vision of the center, but also the cultures of the individual institutions. Universities with strong industry relations prior to hosting ERCs need not invest as much time in recruiting new companies, but need instead to develop more comprehensive communication and retention strategies that reflect upon the center as a whole. In other cases, such as when a multi-institutional ERC has more than one pre-existing industrial consortium, it is vital to develop from the start a clear mechanism for merging the consortia to ensure a seamless transition.

CASE STUDY: *One ERC, associated with five institutions, has two pre-existing industrial consortia. The challenge is to develop a transitional strategy that is* *acceptable to the host universities of the existing consortia, transparent to industry partners with regard to commitments and benefits, and a source of start-up revenue for the new ERC. To achieve this goal, the ERC has built in a two-year transitional period, during which all industry members of the pre-existing consortia are considered members of the new ERC at a level that reflects the same financial obligations but offers expanded ERC benefits. During this period, while new industry partners pay their membership fees directly to the ERC, members of pre-existing consortia continue to make payments to their respective host institutions. To provide start-up revenue for the ERC, a contribution of one-third of this revenue is made to the ERC account. By year 3, the ERC agreement is implemented for all members and their support is paid through membership fees directly to the ERC.*

Other cultural differences that need to be addressed at the beginning of a center include the degree to which the center desires to enlarge its research and education programs, the balance of academic and industrial goals, and the long-term vision. In addition, all of the center's principal investigators must support the center's mission and strategy. Many of these issues can be discussed and clarified in the development of a comprehensive marketing plan.

5.2.2 Membership Structure and Fees

All ERCs expect substantial financial support from industry. ERCs have annual memberships, with responsibilities and benefits governed by a membership agreement. Across all ERCs, annual membership fees range from \$2,000 to \$250,000, usually encompassing two or three membership categories with corresponding fees and benefits of membership. For small companies (often defined as fewer than 500 employees or less than \$30 million in annual sales), fees are generally \$2,000 to \$10,000, and may be graduated. Many centers allow larger firms to affiliate either in limited ways (by research area or by specific contractual projects), with annual fees typically ranging from \$6,000 to \$30,000, or in a broader way (full membership with maximal rights), with fees usually ranging from \$25,000 to \$100,000. Industry-specific differences are important in establishing a fee structure. For instance, the computer software industry usually pays higher fees than others do. Some centers include university overhead on membership fees, while others do not. Policy on indirect costs must be negotiated with the university administration at the inception of the center and established in writing.

Membership fees are pooled and allocated to center functions according to the strategic and operational plans established by the center's leadership. Industrial members may provide additional support above the membership fees for activities such as sponsored research projects, equipment donations, intellectual property donations, or educational grants. Potential industrial members that have not joined the center, but contribute support for projects that fall within the scope of the ERC's strategic plan and are included in the Center's annual report, are not considered members but may be given another designation, such as "affiliates." Some centers use all fees to support research; some use them exclusively for support of student interns; others use membership fees for all operations.

Centers' policies vary on how fees are paid—in cash, in kind, or a combination. Single-institution ERCs may find that in-kind contributions are valuable in the early stages, when equipment is needed and relationships require nurturing, but later, when the facility becomes more fully equipped and working relationships are established, cash contributions may be required of new members.

In multi-institutional ERCs with pre-existing industrial consortia, the needs and cultures at the different institutions and industries may vary. Thus, it is important to maintain, at least initially, the flexibility to negotiate and the willingness to make changes, to arrive at a membership structure that is acceptable to all parties involved.

CASE STUDY: *One multi-institutional ERC devised a three-tiered membership structure (Principal, Associate, and Affiliate) to meet the needs of industries. In addition to regular member's benefits, Principal Members have early access to the center's intellectual property. By working closely with the ERC as research champions and testbed partners, these companies are in position to help guide the center's research direction. Associate Members receive broad benefits such as the annual seminars, short courses, publications, and privileged access to the ERC faculty, students, facilities, and other outreach programs. Affiliate Members provide in-kind contributions in lieu of cash. They represent companies who are interested in having their products used and evaluated by the ERC researchers. The center presented its initial membership structure and fees to its industry counterparts for review and discussion, and received feedback with suggested modifications. After multiple meetings among the center's host universities, revisions were made to the Principal Member agreement to match the voice of industry. The center's willingness to negotiate led to agreements being approved by industry sponsors, and the roster of Principal Members began to grow.*

In 1999-2000, ERCs reported corporate memberships ranging from 14 to 83 companies per center (averaging 35). The distribution of membership among large, mid-size, and small companies depends somewhat on the industry involved, but most centers have members in all three size categories. Overall, Fortune 500 companies constitute the largest proportion of the current ERC memberships (nearly half). In addition, several centers have federal laboratories as members, and some include industrial consortia. Overall, for established centers member companies provide from 25% to 55% of total income (about 30% of total income for ERCs overall).

5.2.3 Membership Rights

During its first year, each ERC develops a standard membership agreement that governs members' participation and sets out the forms of cash and in-kind contributions that constitute membership. Organizations that can be considered as members include private firms and local and Federal agencies. Organizations contributing research and educational participants in the center, such as other universities, institutes, and hospitals, should not be counted as members. An ERC should be mindful not to develop unique contractual arrangements for each company in lieu of a membership-defined program of industrial collaboration. However, member companies may augment their support to the center through directed project support or contractual arrangements. Firms that are not members but provide directed project support often are classified as “affiliates” and firms and others that provide equipment and other donations are classified as “contributing donors.”

Guidelines for ERC industrial membership agreements, including example agreements, are available to registered users of the ERC Association website at <http://www.erc-assoc.org/topics/6-b1.htm>. See also Attachment A to this chapter. Standard membership agreements should address such issues as:

- Membership definition (e.g., members have nonexclusive equal access to any intellectual property developed under ERC funding; access to all meetings and workshops, interns, technical information, research collaborations, and placement of industry people in ERC labs; input into the research planning and review process; and a seat on the center's industrial advisory board)
- Fee clarification (appropriate membership categories and associated fee structure)
- Intellectual property (IP) rights (discussed in Section 5.4)
- Publication issues (usually governed by university policy)
- Membership termination (some centers require a two-to three-year membership commitment, or an extended—e.g., nine months—notice of termination to prevent undue impact of the funding shift on students' support).

One ERC reported that an improvement on the initial contract would be a provision for modifications that would not require full legal approval. For example, fees could be changed by approval of the Industrial Advisory Board (IAB) with 12 months' notification of members.

Intellectual property rights arrangements specified in the membership agreement are influenced by the type of industry, by the university's experience, and (it is to be hoped) by common sense. The type of membership structure also should influence IP decisions. If all the center's research activity is precompetitive and supported in common, shared rights for all members are appropriate. If the center has, in addition to generally supported research, special project support by a company, the arrangement should reflect that company's unique contribution and rights. In a typical center, the university owns IP and licenses are available to members. Access to licenses is based upon membership category, varying from royalty-free license to all center-developed IP to no access for any members. Other IP issues that may be included in the agreement or dealt with on a case-by-case basis include restrictions on licenses, who pays for and maintains patents, and royalty amounts. A more extensive discussion of IP rights is presented in Section 5.4.3.

5.2.4 Member Responsibilities—Boards and Committees

A center's organizational chart reflects the formal role that industry plays in advising the center. All centers have industrial advisory boards or committees that serve functions such as the following:

- Provide advice on developing the strategic plan

- Review overall progress against strategic goals
- Suggest changes to the strategic plan, research, and education efforts
- Identify areas for cooperation with industry or, in some cases, other institutions
- Discuss the strategic plan and suggest modifications based on research results
- Review invention disclosures and suggest patent action
- Critique the progress and direction of each research project
- Provide resources the research program may need
- Appoint industry speakers for workshops and seminars
- Carry out an annual SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the ERC.

Because these activities are both technical and managerial, many centers have corporate advisors who come from both those groups within companies and who form two different types or levels of center advisory bodies (see case study). In most centers, the technical advisors meet formally at least twice a year; upper-level management advisors usually meet annually. A company's membership category determines how many advisors it may have and at what levels. Advisory committees may be chaired or co-chaired by industrial members, usually vote on key issues, and often have minutes and action items distributed.

The two main customers of an ERC are its students and industrial partners. It is essential, therefore, to make sure that the ERC's initiatives match the voice of its customers. One way to ensure full endorsement is to engage them in the formulation and implementation of the ERC's initiatives. The Student Leadership Council and the IAB, along with its subcommittees, are the center's best resources for support and collaboration.

CASE STUDY: *In one ERC that has multi-tiered memberships, the IAB consists of all the Principal Members and elected Associate Members, with representatives from both the technical and managerial levels. To address various issues, such as IAB policies and procedures, proposal review, benchmarking, and communications, individual IAB working groups are established with specific objectives and milestones. The IAB chair, co-chair, secretary, Industrial Liaison Officer, and Center Director hold weekly brainstorming huddles. The smaller IAB Executive Committee meets via monthly teleconferences to stay abreast of progress and developments, and the full IAB gets together on a quarterly basis to discuss broad base issues. Face-to-face full IAB meetings are held twice a year, in conjunction with the site visit and the annual seminar/review. By breaking out into subgroups, the IAB members are able to share responsibilities and guide the center without feeling overburdened.*

At times, some ERC members may feel the need to explore research directions that do not map perfectly onto the ERC's core research goals. It is the ERC's responsibility to meet this need by collaborating with these companies under other mechanisms, such as sponsored contract research or fellowship research. ERC industry partners should be made aware of the various collaborative opportunities and should have a clear understanding of the difference in IP policies under the various options, especially if it involves a multi-institutional ERC.

To build a partnership with industry in strengthening their ERC, each IAB is asked to carry out, once a year, an analysis of the strengths and weaknesses of the ERC in its basic features: vision and strategy, research, education, industrial collaboration, leadership, and management. The advisory board is also asked to determine whether there are any key weaknesses, constituting threats to success, or any missed opportunities that must be addressed. This "Strengths, Weaknesses, Opportunities, and Threats" (SWOT) analysis is shared with the ERC, the ERC's NSF Program Director, and later with the NSF site visit team. (See Section 5.3.3.5 for further description.)

The operations at one ERC provide a case study of the interactions between an ERC and its Industrial Advisory Board.

CASE STUDY: *The Center for Biotechnology Process Engineering at the Massachusetts Institute of Technology has an Industrial Advisory Board of senior managers from leading biotechnology and pharmaceutical companies. They are in an excellent position to assess center activities in terms of both intellectual context and industrial relevance. The IAB's annual meeting provides assessment and advice on broad strategies, but not on specific details.*

When financial support is requested for specific collaborative projects, the IAB members act as overseers for those commitments. Research managers, who may be the relevant IAB members or other designated personnel from within their companies, form the core of formal technical advisory groups for the various collaborative projects. These groups meet twice each year for one or two days; informal interactions occur approximately monthly. By and large, the perspective of the project research managers within their home organization is one of shorter-range goals and objectives than those with which the senior managers are concerned, a perspective with defined technological barriers. They serve as the conduit for identifying specific individuals or groups within their companies for detailed collaborations and as the interface with the company's upper management. As champions for these interactions, the research managers serve the important function of securing the necessary financial support for the collaborations.

The most effective type of interaction for rapid technology development and transfer is frequent (day-to-day) and personal (one-on-one) interaction with company researchers. Constant dialog among the ERC faculty, students, and research staff with the corporate research managers and research staff, for purposes of planning and assessment, allows responsiveness to new information from both the company and the center. These working collaborations often involve the use of company facilities and the development of new projects in response to company problems, which in turn leads to additional involvement in the center on the parts of member companies.

In considering the structure of a prospective IAB, several guidelines can be offered. First, it is important to remember that it is an advisory body. Final decisions should remain with the center management. Of course, ERCs should always try to heed the advice given by this body, but extenuating circumstances, conflicting input from other company personnel and from NSF site visit teams, and other factors may have to be integrated into the final resolution. It is also important in the early years of a center to accustom the IAB to thinking longer range; the university structure is not equipped to put out today's fires. Another key point is that research results will be commercialized only if they are relevant to industry needs. Thus, it is important to get the IAB involved in planning the research program to ensure that it will be relevant when completed.

5.2.5 Role of the Industrial Liaison Officer

Even though no standard model exists, NSF requires every ERC to have someone on staff, often called an Industrial Liaison Officer (ILO), who is responsible for establishing and maintaining a liaison between the ERC and its industrial sponsors. Each center needs to decide during the start-up and development phase how they are going to carry out this function. This section draws on the experience of several individuals who have functioned in this capacity at ERCs during various stages of center maturity.

5.2.5.1 Structure of the Position

The first consideration is what role the Industrial Liaison Officer will play in the center. If the senior faculty and Center Director are too busy or not prepared to market the center, then the ILO's role in marketing is primary. The ILO must then be someone who has the recognition and respect of both the faculty and industry, who can articulate what the center has to offer and can generate enthusiasm for it. If the center's reputation is already well-established and/or there are effective salespeople in the form of the Director and key faculty, then what may be needed is a capable, people-oriented, detail person whose primary objective is to provide customer service. He or she can make meeting and other arrangements, coordinate industrial visits, disseminate information, and deal with routine issues that may arise. In most centers, the ILO is somewhere between these two poles.

The Industrial Liaison Officer is not always a single individual. Centers staff the function of industrial liaison/technology transfer in different ways. Several have one or more professionals engaged solely in the industrial liaison effort; others use one staff person for multiple functions within the center, including industrial liaison; and a few use only faculty and students in the liaison function—although the latter approach is not recommended. Industry input suggests that having a dedicated person in this role may be the most successful model, with the greatest likelihood for maintaining consistency and improving the ERC-industry interaction. In a multi-institutional ERC with no pre-existing industry participation, it is wise to establish a single industrial liaison position. This person will be responsible for recruitment and retention of members and will serve as the single point of contact within the center for industry-related matters.

Many ILOs have experience working in industry and find this industrial perspective helpful. Most report to the Center Director and work directly with faculty, industrial researchers, and often with students. If the Director has high industry exposure, then the industrial awareness of the ERC is heightened. Visibility of the ERC is further enhanced when the Director travels extensively and gives presentations at technology meetings attended by academic and industrial scientists and engineers. The visibility and reputation of the center rise to an even higher level if the key faculty also play a role in marketing the ERC when they are on the road giving presentations. It is the nature and quality of the research that attracts customers the most.

Another ERC advantage that attracts industry is the opportunity for integrating research and education. It is thus essential for ERC industrial liaisons to ensure that their industry partners are optimizing their investment by becoming fully engaged in the ERC's education and outreach activities. Other than professional short courses and workshops, ERC industrial outreach initiatives may include internship programs, fellowship programs, mentorship programs, and industrial residence programs. The case study below illustrates a prime example of a partnership that benefits both the ERC and its industry partner in research and education.

<u>CASE STUDY</u>: *A technical area was identified at a site visit as a weakness of the ERC. Within a few months the ERC formed a working group, with industry advisors, to address this weakness. The working group organized a workshop to bring in broader industry input and guidance. As a result, a mentorship program was established, in which ERC students were identified and designated to work directly under industry mentors. The students not only gain technical knowledge, but also learn how to correlate what they've learned with the ERC research program. This partnership has enabled a close working relationship with industry and has provided valuable first-hand industry insight for the ERC.*

One concern voiced by several Industrial Liaison Officers is the lack of perceived value and recognition for their function by the university, and by a few Center Directors. One suggestion to improve the image and perceived value of the Industrial Liaison Officers within the university is to have them give regular university-wide seminars, with overviews of the technical challenges and opportunities afforded by the ERC's technology and research. Another suggestion might be to include them as members of teaching teams, to bring the industrial perspective to students in a broad range of courses.

It may be important to establish the ILO position as an integral part of the center management team during the formation of the center, even though their roles could become more critical to the success of the center as it nears the end of NSF support. The ILO should play a key role in the development of the center by providing a direct interface with industry members. Faculty/industry interaction can effectively address only engineering and science issues, while the ILO becomes responsible for nurturing the long-term relationship with the industry members. It is these relationships with industry that will become important to the center as it approaches self-sufficiency. The ILO should, above all, work to ensure post-NSF survival of the center.

5.2.5.2 Most Important Aspects of the Role

At a meeting of all ERC Industrial Liaison Officers, the following list of duties for this position was generated, grouped according to prevalence among the respondents. The

ILO at any given center is likely to have many of these responsibilities, especially those in the first groups.

Nearly all respondents mentioned the following as important components of their position:

- Customer service
- Company recruitment
- Marketing the center
- Member relations
- Identifying center research activities relevant to industry needs
- Facilitating faculty interactions with industry
- Showcasing the center
- Membership on management team
- Developing informational materials such as newsletters, brochures, websites, etc.
- Helping to prepare annual report
- Collecting and organizing data for NSF indicators report.

In addition, several respondents mentioned the following:

- Managing intellectual property
- Representing the center on councils of other organizations
- Identifying new business activity
- Proposal writing
- Conference planning
- Customer satisfaction measurement
- Student/industry relations (internships, seminars, jobs, etc.)
- Representing the center on university committees.

Regarding the management of IP, an ILO attending the group meeting said, “I am a firm believer in the ERC concept—especially the transfer of useful technology. I also believe adamantly that the ILO needs to be actively engaged as an overseer in all stages of tech-transfer, regardless of how integrated his/her functions are in this area. Even with centers where a solid outside agency is handling the details, the ILO sits in the best seat to evaluate and facilitate the progress toward the true goal: to get new industrial products introduced into the marketplace. I think that this point needs to be stressed—that the ILO can make or break this aspect of the ERC. With all objectivity, it seems that this part of the ERC mission is the most difficult to accomplish, and the NSF needs to have a lot of successes in this column to continue to justify the program. This is what industry wants and needs.”

A few respondents cited the following as important components of their position:

- Negotiating contracts
- Research project management and contract management
- Joint venture planning
- Preparing technical reports and abstracts.

Several centers' Industrial Liaison Officers cited "establishing and maintaining seamless linkages with industry" as being vital for the development of an integrated university-industry team working together on a research agenda. Important communications for which the Industrial Liaison Officer is the conduit from industrial members to center faculty include:

- Priority and criticality of research objectives
- Trend and projections of industrial needs
- Collaboration opportunities for the center.

Likewise, the important communications for which the Industrial Liaison Officer is the conduit from center faculty to industrial members include:

- Objectives and plans of the research groups
- Progress and findings of the center's research
- Collective experience (nonproprietary) from other members.

Loyalty to both the center and industry allows the Industrial Liaison Officer to bring together unlikely partners and facilitate the collaboration and transfer of technology in a way that increases industrial support for the center. Many find that a technical and/or industrial background helps them communicate effectively with industry to facilitate interactions, explain the benefits of participation, and communicate to the Center Director, faculty, and students how best to strengthen collaboration with industry. Given the broad responsibilities of the ILO, it is imperative that the ILO work closely with the center's Director to establish priorities and objectives to ensure that the industrial collaboration goals of the center are met.

5.2.5.3 Most Satisfying Aspects of the Role

Just as they define their job responsibilities differently, various Industrial Liaison Officers also define job satisfaction in different ways, to some degree as a function of their specific job structures within particular centers. The following quotes from Industrial Liaison Officers regarding some of their most positive experiences may provide a better appreciation of their role and the types of activities in which they are typically involved:

> "Many aspects of my position are exciting, but one that provided a great deal of satisfaction was my role in persuading one of the key members of the center to continue as an industrial sponsor. This company had been a member of the center for several years at the highest level of membership and provided substantial financial support. Due to personnel changes and changes in corporate strategy, the company was reviewing the advisability of their continued participation in the center. Our center was in real danger of losing one of its most important members, and as a result of the on-going discussions, the company had become two years behind in their membership fees. This presented two distinct challenges, one being to convince them of the benefits of continuing their membership and the other to recover compensation for the previous two years. Through meetings with key personnel, we were able to document the benefits of

past and continued membership, the value of a compromise plan (including benefits for paying overdue fees), and the advantages of reorganizing the company's interaction with the center. Today this sponsor is one of the leaders of the center and the industry."

"One of the best experiences I've had in my position resulted from a talk I gave about the ERC at a technical meeting. An attendee at that meeting was impressed with our research, and persuaded his company to join. A very large multi-year research contract funded by this company is now under way, and I participate in the research project by providing coordination of activities at four of our ERC universities. The research is progressing well, and the company has reported that compared with other (non-ERC) university research they've funded, this project is actually producing results. They are in fact planning a new product line based on the development of this technology, and have moved up the product introduction schedule because the research is progressing so well. I feel that this case is a validation of the ERC concept."

"I've had many good experiences, but originating an idea for a joint project with a small local company and teaming up our faculty with the company on a proposal to our state government was an exciting process of making collaboration happen. The project also involved students in a class working on a problem in this area for credit. We were successful in matching the technological need of the small company with the academic/ERC interest in creating new design methods for that particular application area. We developed a joint proposal with the company by first inviting the company vice president to a design class, at which he described the company's business and outlined the problem to the students. Student teams were assigned to do a patent search on the desired process and, highly motivated by the opportunity to work on a real-world problem for a customer, they submitted reports that summarized the patents and other research literature. One report whose quality was exceptional was appended to the proposal that we subsequently submitted jointly with the company to the state technological development program."

5.2.5.4 Most Difficult Aspects of the Role

Two difficulties plague many Industrial Liaison Officers: (a) insufficient time for multiple activities and (b) the challenge of motivating faculty members to take timely action on opportunities to interact with industry. Time management skills are an absolute requirement for success as an Industrial Liaison Officer. Lack of support staff is a serious drawback for many. Most Industrial Liaison Officers are realistic about budgetary constraints, but still would value technical support staff. Some expressed concern about having insufficient input into center budgetary decisions.

Other challenges faced by the ILOs have included:

- Mediating between industry and faculty researchers when projects don't go as planned

- Additional coordination among industry champions and faculty researchers on the respective campuses in the various subthrust areas, especially for multi-institutional ERCs.
- Having to "fire" a visiting industrial researcher while still maintaining his company's involvement and support;
- Protecting the intellectual property of individual companies while developing opportunities to expand industrial involvement;
- Learning to work with both company and university personnel in parallel to move an idea forward; and the loss of member companies from the center;
- Providing mechanisms for researchers and industry representatives to meet and exchange ideas that may lead to sponsored research projects in the center;
- Creation of a team environment where center and industry researchers can effectively collaborate and communicate on their projects.

In the case of a multi-institutional ERC, the Industrial Liaison Officer may assume the delicate role of coordinating inputs from industry champions and their respective faculty researchers on various campuses. Competing for the attention of these various individuals, with varying priorities, personalities and working styles, is a real challenge. To avoid overwhelming and overloading the center's resources, the ILO must make sure that announcements are made in a timely manner and requests are sent with clear and precise instructions.

One of the more challenging aspects of the Industrial Liaison Officer's role often involves issues regarding intellectual property. (See Section 5.4, "Intellectual Property and Commercialization.") As mentioned earlier in this section, IP rights are an important benefit of center membership for industry. However, intellectual property obligations to sponsors can also impose barriers in negotiating new joint ventures and licensing technology to other companies. It takes work to learn enough about the options in dealing with conflict of interest and how to handle rights, but these skills are at the center of the ILO's responsibilities. The following example of a problem dealing with conflict of interest illustrates these difficulties.

CASE STUDY: *At one ERC, a full-time senior research associate, who was one of the designers of a specialized advanced integrated circuit board as part of his center research activities, sold the design to one company and was negotiating to sell it to a second company and another university. These transactions, which were unauthorized and illegal since the intellectual property belonged to the ERC and the university involved, were discovered as a result of an internal university audit. The Industrial Liaison Officer at the center was unsure of how to handle the situation and of the options that were available. The university's internal audit group, however, was able to provide guidance that was extremely helpful in resolving the problem. As a result, the researcher was terminated, the company that had purchased the design agreed to use it for internal research purposes only, and transactions with the second company and the other university were stopped.*

5.2.6 Lessons Learned: Establishing the Program

- Developing a reliable computer-based tracking system for industrial interactions is essential.
- Developing a standard membership agreement that will stand the test of time is important.
- Building long-term industrial relationships should be the focus of substantial effort.
- Policies concerning the distribution of intellectual property rights among member companies, the ERCs, and the university should be flexible and appropriate to the nature of the industry and the membership structure.
- Because of the diversity of the role, clearly established boundaries help an Industrial Liaison Officer thrive.
- Staff support for the Industrial Liaison Officer, if affordable, can greatly facilitate the success of the center's industrial interactions.
- Support for faculty members should be restricted to those who interact with industry or are willing to begin doing so.
- Close interaction with industry is necessary to ensure effective two-way communication.
- Respect from faculty members is often hard to achieve in a nonfaculty role; the Industrial Liaison Officer should make special efforts—such as giving seminars—to increase understanding of his/her role.
- Flexibility—for example, in membership levels and fees—is essential in the start-up phase of an ERC.
- Effective planning is essential, but remember that one cannot plan for all possibilities, so it is necessary to remain flexible and open to opportunities.
- Key issues in establishing membership agreements include:

– Complexity or simplicity of agreement vs. addressing critical issues downstream
– Granting intellectual property rights (industry driven)
– Identification of negotiable terms with university
– Flexibility to negotiate vs. commonality
– Subcontracts with partner universities (invention reporting and handling when combining ERC research sponsorship with previous or other sponsorship; division of returns)
– Need to establish baseline agreements before implementing marketing programs
– Recovering from earlier versions. (It is easier to expand than reduce benefits.)

5.3 BUILDING AN INDUSTRIAL CONSTITUENCY

5.3.1 Attracting Corporate Members

The need to attract new members continues long beyond the start-up phase, as all centers experience turnover in membership due to shifts in corporate strategies and fiscal constraints. Many centers have formal criteria, often developed with the Industrial Advisory Board, for identifying those companies that may belong to the center. These criteria deal with issues such as foreign firms and multinationals, whether consulting firms may belong, and whether company size or location limits membership. (It is noteworthy that, while some centers have a geographically concentrated membership, no center limits membership based on location, and many have all of their members at long distance.) This section addresses successful strategies for recruiting appropriate members.

5.3.1.1 Strategic Plan for Recruitment

The Industrial Liaison Officer manages this activity. Centers vary significantly in the formality of their strategic plan for recruiting member companies. A few centers function only in response to inquiry, without active recruiting (not a wise approach). Most of the centers focus on identified industry groups (sometimes with IAB input) and establish membership goals, do market research to further identify appropriate company prospects, and tailor recruitment strategies for each prospect. This approach is recommended.

5.3.1.2 Marketing the Center

Every center uses its Director, staff, faculty members, and sometimes students in its marketing efforts, actively or responsively. At least one center uses a part-time consultant to contact potential sponsors to identify and explore areas of mutual interest. It is the high quality of research (and graduates) that is always most valuable to companies. Carefully identifying the companies that might benefit from the research in the center—that is, finding the right partners—is important in successful marketing. Presenting information about the center’s respected faculty members must be accompanied by clearly defining the value of center participation from the company’s perspective. This is particularly difficult in industries with a poor track record for R&D funding. Marketing techniques include literature, newsletters, and brochures; visits to industry by directors and faculty; visits to the center by industry representatives; booths and exhibits at trade association meetings; participation at technical society conferences; publication of technical papers; participation in industry research consortia; a center website; informational videotapes; letters to potential industrial sponsors identified through contacts; and topical workshops.

Consider that it may also be in the members' best interests to join in the recruitment process. If so, it is important to arm member "recruiters" with information about the center and its industry partner program. Additionally, the center's recruitment of industry support may align with and add to university or school development program goals. If so, leveraging the assistance of institutional development officers may help in identifying prospective members.

Centers disagree on the value of various printed materials in marketing, but most believe that personal contact (at professional and trade meetings or other "natural" venues) and visits are very effective. Particularly valuable, it is thought, are visits to companies by teams composed of center faculty, Director, and Industrial Liaison Officer. These visits not only introduce the center to a broad audience of company personnel; but also help the ERC understand the company's products, business climate, and issues so that the value of ERC membership can be specifically defined. In arranging such a meeting, the Industrial Liaison Officer should gather in-depth information on the company, brief the Director and faculty, and set objectives for the meeting in advance.

The Internet may be an increasingly productive source of low-cost "passive" leads. One center found that several industrial contacts had resulted from companies referring to the center's website. Special sections of the site geared to industry can be valuable; some ERCs have established password-accessible pages for members.

5.3.1.3 Industrial Consortia and Governmental Groups

Several centers have worked with external industrial consortia and/or with state and local governments—particularly those agencies involved in economic development. Besides meeting specific consortium or agency goals, such interactions need to pass the test of leveraging the center's activities, augmenting the benefit to member companies, and contributing to student and faculty development. Several centers collaborate with state agencies in programs with small companies—from directed research projects with undergraduate students to state-assisted start-up companies based on center research. One ERC is active in the industry's trade association and serves on national councils and task forces. The Center for Biofilm Engineering and others have developed flexible consortia around specific testbeds. Other centers, such as the Data Storage System Center, have been the nuclei of large, formal consortia in their areas of research (as explained in the following case study).

CASE STUDY: *The Data Storage Systems Center (DSSC) at Carnegie Mellon University, owing to its prominence in the field and its robust systems infrastructure, was able to provide leadership in forming and developing the National Storage Industry Consortium (NSIC). DSSC has worked successfully with NSIC members to develop several cooperative university/industry research thrusts in data storage systems technology. NSIC—a joint-venture consortium of 26 U.S. industrial companies, 27 universities, and several national labs and agencies formed to promote and support collaborative research with academic, industrial, and governmental participants—has helped the United States maintain world competitiveness in this area by organizing cooperative research projects and effective technology transfer among member organizations. Incorporated in 1991, the DSSC continues to be a key contributor to both the strategic direction and the research output of the NSIC program. The founding*

Director of NSIC said that NSIC would not have been able to establish its magnetic and optical recording programs without the leadership of the DSSC.

NSIC has launched a number of cooperative university/industry research projects in ultrahigh-density recording, funded by the U.S. Department of Commerce (through the National Institute of Standards and Technology [NIST]) and the U.S. Department of Defense (the Defense Advanced Research Projects Agency [DARPA]). The DSSC is a key research participant in nearly all of these projects and was instrumental in the success of the proposal process for each of them. In fact, a DARPA-funded NSIC project in ultrahigh-density recording was the result of a DARPA contact initiated by DSSC personnel, who demonstrated the need for support for cooperative industrial and university research in the data storage industry. The Center also worked with NSIC to convince NIST to select digital data storage as a focus area for the Advanced Technology Program.

NSIC's research program in Extremely High Density Recording for hard disk drive (HDD) technology was begun in 1996 with four industrial sponsors and expanded in 1998 with the addition of NSF sponsorship and funding, administered by the DSSC, under the NSF Frontiers of Magnetic Recording Program. In 1999-2000, the program had grown to 8 industrial sponsors and had a $1.9M budget, supporting nearly 40 graduate students.

5.3.1.4 Start-up and Small Companies

Identifying mutually beneficial relationships with start-up firms and small companies is challenging for most centers. These companies' small R&D staffs and immediate product concerns often hinder them from participating actively in center research projects and activities. When approached, their initial reaction often is that they may need immediate consulting assistance or they want to hire students, but could not benefit from full membership in a center. Nevertheless, in high-risk research areas such firms may represent an important mode of technology transfer. Most centers have developed special ways of working with small companies to make joining possible (such as reduced-rate memberships or short-term project teams of undergraduate students with faculty and industry researchers). Marketing the center to such firms can emphasize benefits such as access to prospective product buyers from large companies at meetings; a window on the future directions of the technology; access to prospective employees; and any special programs developed. Teaming with small firms on proposals to other agencies also is an effective way to establish a partnership.

Most states have programs to support the development and commercialization of technology by small companies. They may provide business incubators, help in applying for Small Business Innovation Research (SBIR) grants, matching funds for federal grants, or even direct equity investments through venture or seed capital funds. A useful source of information is the State Science and Technology Institute, a nonprofit research and education organization that tracks such state programs and monitors the state-federal relationship in science and technology. It can be found on the Internet at <http://ssti.org>.

The following case study describes a mechanism one center developed, with assistance from the state government, to encourage small companies to participate in the center.

CASE STUDY: *The Center for Biofilm Engineering is in Montana, a lightly populated state with limited industry. Most companies in the state employ fewer than 50 people. The center made a strategic decision to help such companies. A key part of that decision was to allow small Montana companies to participate as members at no cost. The state provides the center with $200K per year—a grant from the Montana Science and Technology Alliance—and with that support, larger member companies were persuaded that small state companies could have a combined membership, with one collective vote on the advisory committee. The result is a recently developed consortium of Montana-based small businesses, the Montana Biofilm Research Consortium (MBRC), which can benefit from interaction with Center researchers and industrial members. The MBRC has 11 members from a range of industries, including biomedical research, sterilization technology, mining, wastewater treatment system manufacturing, and regulatory enforcement. Requirements for MBRC membership include a Montana-based operation, under $2 million in annual sales, and the potential for beneficial interaction with the ERC. The Consortium's goal is to transfer center-developed technology to Montana small businesses, and a key component of the program is working closely with these companies in writing collaborative proposals. In the first year of this program, the Center received eight grants, totaling more than $300,000, for collaborative R&D efforts with six of these companies.*

Section 5.4.3.2 provides further discussion of small-company issues from the standpoint of intellectual property rights.

5.3.1.5 Foreign Firms

NSF recognizes that an ERC may have a global dimension, since many research and education challenges and opportunities require overseas collaboration to bring the best resources to bear on a problem. NSF policy permits foreign firms to be involved in an ERC if they agree to operate on a *quid pro quo* basis, exchanging personnel, sharing support, risks, benefits, information, and their own facilities to the same degree as all other participating U.S. firms do.

In 1999-2000, about 10% of all ERC industrial partners were foreign firms.

5.3.2 Involving Industrial Members

Key to a center's impact through relevant research and potential student hires is the depth of commitment and active participation of industrial researchers in center programs. Exploration by centers of the best ways to achieve a sense of "seamless community" with their partners attests to the creativity and flexibility of center personnel. This section summarizes centers' experiences in encouraging involvement by industrial members.

5.3.2.1 Industrial Input into Strategic Planning

Strategic planning for the center's research, education, and industrial collaboration and technology transfer programs is a vital segment of the activities of all ERCs. Their charter with NSF requires that ERCs periodically identify goals in each area of operation, establish paths to their objectives within an identified time, outline how resources will be organized to achieve objectives, make assumptions about the state-of-the-art and future expectations, and evaluate their progress toward their goals.

Most centers rely heavily on their sponsors and industrial advisory groups for input into their strategic planning. There are several vehicles for doing this, some formal and others informal. Some advisory boards and technical advisory groups hold special strategic planning sessions; some consortia engage in road-mapping activities. Several centers survey members to gather initial information for planning discussions, including recommendations for and evaluation of new projects. One-on-one interviews are also employed. The experience of the University of Washington Engineered Biomaterials ERC, or UWEB, illustrates how some centers go about this process (described in the following case study).

CASE STUDY: *At its annual Sponsors Meeting, the University of Washington Engineered Biomaterials ERC (UWEB) spends about half a day with participants broken into about a half-dozen "focus groups". Each group discusses a major research topic area at the ERC. One faculty and one industrial person co-chair each session and these sessions are held at the very end of the meeting, so all new information is also on the table for discussion.*

The goal for each group is to identify scientific barriers that impede or even prevent the companies from manufacturing and marketing the products they want or know they need. UWEB also tries to include clinicians, scientists, and students in each discussion group.

The very last session of the annual meeting is for the entire group to meet and listen to the co-chairs summarizing the focus group results. The focus group summaries from one year are documented and reintroduced the next year for comparison.

The objective overall is to incorporate industrial input into UWEB's research. In this way, UWEB research is kept relevant and up-to date, so that the scientific barriers confronting the industry can be surmounted.

5.3.2.2 Mechanisms to Enhance Interactions

Of all the approaches used to expand and deepen industry involvement in centers, nearly all centers agree that the most effective are personnel exchanges and joint research activities, both of which foster one-on-one interaction. Successful collaboration must benefit both the collaborating individuals and the cooperating organizations sufficiently that obstacles (and there are many) will be overcome. One center Industrial Liaison

Officer uses the “health club analogy” with industrialists (the more you participate, the more you benefit).

Most centers attempt to broaden their interaction with member companies and provide a variety of ways in which companies can interact. Frequently used mechanisms that have been found to be effective include:

- Student internships at company sites
- Student mentoring by industry
- Industry participation on thesis committees
- Faculty sabbaticals
- Extended visits by industrial researchers
- Technical review meetings (review and topical)
- Industrial Advisory Board meetings
- Visits (of varying lengths) by industry to the center and by the center to industry
- Collaborative research projects
- Contract research projects
- Consortium meetings
- IP licensing
- Hosting center tours for members and their clients/prospects
- Tours of member facilities by visiting colleagues
- Short courses.

It is important to develop one or more champions within each company. Usually these will be firms’ representatives to the IAB, but there may also be an additional strong supporter of the center within the company's top research management or general management. These people go to bat for the center when continued membership is an issue. They may be proactive in disseminating center products and information within the company; and they look for joint research opportunities. An enthusiastic and forceful champion—preferably in a senior executive position at the company—makes the difference between a strong corporate member and a *pro forma*, uncommitted one. In one company, the center's champion died and the center subsequently lost the support of the company. If the industrial representative must step down, due to transfer, promotion, or other cause, it is crucial to enlist his or her help in identifying a suitable replacement champion.

5.3.2.3 Industry/University Collaborative Research Teams

ERCs have found that close, personal liaison and one-to-one collaborations with industrial sponsors are very effective methods of technology transfer. Most centers have established cooperative projects where center personnel and industry partners have specific responsibilities and meet regularly to review progress and determine directions. In some cases industrial researchers provide leadership on project teams.

Faculty members join ERCs because of their interests in industrial problems and in systems-oriented, interdisciplinary research. Centers encourage this inclination by making funding available for research done cooperatively with industry. In some cases, specific projects or contract work are equally as effective in promoting industrial collaboration. Faculty members learn about industrial interests (and those of academic colleagues) through participation in center reviews, visits by and to companies, and serving on thesis committees with industrialists. Some centers provide released time and salary support for faculty; others do not.

In some centers, research collaborations have extended to groups of companies, consortia, and other universities. (The NSIC case study presented in Section 5.3.1.3 is an excellent example.) Successful research collaboration between faculty and industrial researchers then becomes part of the culture of a center. Graduate students trained in this environment assume that it is a normal and effective way to pursue industry-relevant research. They take that orientation with them as they go into careers in academe and industry.

<u>CASE STUDY:</u> *A good example of collaborative research teams was seen in the Industrial Fellows Program of the University of Minnesota's now-graduated Center for Interfacial Engineering. The explicit goal of the program was to build personal bridges between the company and the university and Center culture while accomplishing relevant research. Industrial researchers spent up to a year on campus working with faculty on jointly defined precompetitive research projects. The center provided office space, laboratory facilities, and normal faculty perks; the company provided salary and expenses (receiving in return a $50,000 rebate on full membership fees). During the life of the program, nearly 100 individuals from some 25 companies were Center Industrial Fellows. Flexibility was critical to the program—the schedule for the fellowship was completely open to whatever worked best for the individuals and the project. Some companies used teams of fellows; others linked one fellow with teams of faculty members and students. Companies that integrated the program into their long-term R&D strategy benefited significantly. For example, one firm sent an Industrial Fellow focused on a specific project; the next year they generalized the project with another Fellow. Graduate students spent time in the company's laboratory. This single long-term project involved five Industrial Fellows, four center faculty members, three undergraduates, five graduate students, and three post-doctoral researchers. The work contributed to five Ph.D. theses, numerous publications, and two important U.S. patent awards for the company, which were commercialized. Two of the Industrial Fellows received the company's prestigious Technical Achievement Award for research begun in the center. Another Fellow's project resulted in the development of a substitute for a catalyst used in the manufacture of fluorocarbons.*

5.3.2.4 Information Exchange with Companies

One problem identified by centers is how to share information broadly within member companies when active participation often is limited to a few individuals within each company. This is a two-way problem, with faculty members needing to know more about the company's interests and industrial representatives needing a fuller understanding of how they might benefit from the center. Most centers try to distribute written materials as widely as possible within member companies. Publications distributed by most centers include newsletters, technical reviews and annual reports, reprints of research articles, information on intellectual property, and summaries of meetings of advisory groups. Assessment of the effectiveness of these materials varies; each center must determine what works in its own industrial environment. Many are using extensive center websites and companies' internal electronic mail systems to share information. Others are trying electronic forums and video-conferencing as ways to broaden awareness.

As much as possible, communication should be individualized to the corporate culture of each particular company, to facilitate communication and increase awareness of the center—within large companies particularly. One experienced Industrial Liaison Officer notes that, "it is healthier to communicate some with a lot of people within a company, than to communicate a lot with only a few."

In contrast to the mass distribution of written information, all centers hold formal research review meetings and engage in discussions both during visits and informally, one-on-one. These sessions allow highly effective two-way personal interaction (see Section 5.3.2.2). Agendas for these meetings need to include significant time for industrial participants to interact with the material and its presenters. The traditional academic one-hour presentation—with an introduction, methods, results, summary, and conclusions—involves one-way communication that may be inappropriate for an industrial audience. One center uses 20-minute presentations with the conclusions up front, a brief description of methods and results, and a repeat of the conclusions at the end, followed by 20 minutes for discussion. Others use shorter, 10-minute, presentations with 5-minute discussion periods. Other centers use their own variations. The point is to meet the audience halfway by making the sessions interesting from their perspectives and leaving time for listening and interacting. No matter what format is used in research review meetings, it's important to plan and manage the presentations to ensure that they are aimed at the industrial audiences' interests and needs. The industrial audience wants to know the industrial relevance and application up front, while academic presentations typically start with a strong focus on the "science" and pay little attention to applications, except as an afterthought. It is important to keep cultural differences like this in mind whenever the ERC presents its results to industry, to clearly demonstrate the value that industry sponsors are getting for their investment in the ERC.

Research review meetings include all researchers (faculty, students, and industry); in some centers they are open to all interested companies and in others are for members only. A few centers with closed meetings allow prospective members to attend one session as a marketing tool. Some centers mix a public meeting/dinner on one day with a closed member meeting on the second day, thus giving prospective members the opportunity to interact with current members without being part of the exclusive group. Some of the centers charge company representatives for attending meetings; others include the costs in membership fees. Some centers use hotel meeting facilities, while others hold the meetings at university sites. In either case, proximity to ERC facilities allows tours and laboratory visits to be included, either formally or informally.

Agendas of research reviews vary from center to center. Typically such a review is held during a 1½- to 2½-day meeting, which may include a plenary session overview of activities; consecutive or simultaneous technical sessions covering major research areas; roundtable discussions (sometimes including an outside perspective, e.g., clinicians for biotechnology); poster sessions (at several centers combined with lunch or a buffet supper); and industry feedback sessions. Some centers use the "raw" feedback from such whole-group sessions for guidance; others have representative technical advisory committees that meet in formal session to codify input. Experience suggests that these committee meetings are more effective with a clear agenda (ideally prepared with industry input), minutes, and action items, and seating around a table rather than classroom style.

Another typical formal center meeting type is a topical workshop, often with topics recommended by industrial participants. These are often one-day sessions led by an academic or industrial organizer (or team). Presentations or panel discussions are arranged with sufficient time for discussion. Such meetings are an effective way to explore possible new research directions for a center.

Centers' (usually annual) meetings with Industrial Advisory Board members vary considerably, but many are 3-6 hours long. Some are chaired by elected industry representatives who set the agenda; others are chaired (preferably with a light hand) by center directors. It is important for the entire leadership team of the ERC (Director, Deputy Director, Thrust Leaders, ILO, and Administrative Manager) to participate in this meeting. Industry participants should be made to clearly understand that this is their best opportunity to guide the ERC and therefore they should not be inhibited in their discussions for any reason. Distribution of the agenda and pre-meeting materials 1-2 months in advance facilitates the meeting. Including the last Board meeting minutes as part of the package is found to be extremely useful in conducting Board business. The ERC needs to include time during the meeting for their NSF ERC Program Director to brief industry on ERCs and also for industry to conduct their Strengths-Weaknesses-Opportunities-Threats analysis of the center. See Section 5.2.4 regarding Board responsibilities.

Informal interaction with IAB members between meetings is common. Visits by companies to the center or by center faculty to companies are often informal interactions facilitated by center staff and/or faculty. The purpose of the visit determines which faculty members, students, and administrators are included. Tours of center laboratories may be appropriate for prospective members or new visitors from member companies. It is helpful for all participants to know the purpose, the participants, and the agenda. Briefing materials for a visit should be digestible during a one-hour plane trip. It is often the responsibility of the Industrial Liaison Officer to determine and track follow-up action items from the session.

Informal communication among faculty, students, and company researchers is usually face-to-face or via telephone, fax, or e-mail. E-mail is a very effective means of communication, as it is time-efficient and flexible as to reception and response. Most

ERC faculty by now use e-mail routinely to communicate with other faculty, students, and their industrial researcher counterparts. Any senior faculty members who are not comfortable with the use of email should have a secretarial interface to email.

Finally, it's critical to note that one of the most important roles played by the Industrial Liaison Officer in communicating between the ERC and industrial sponsors is that of ombudsman or the "voice of the customer" in the ERC. The ILO typically has more direct experience in industry and everyday industry contacts than anyone else in the Center and he or she must be seen as an impartial advocate for the interests of the industrial sponsors—in essence, their internal advocate. Undertaking this role makes the ILO an invaluable resource to sponsors and serves the purpose of the ERC in fostering closer industrial collaborations.

5.3.3 Issues Regarding Industrial Involvement

5.3.3.1 Balancing Long- and Short-Term Research

Despite industry's perennial need for short-term (typically less than a year) problem-solving, several centers reported few problems in matching long-term university research with industry's need for longer-term R&D. The continued participation of companies in centers, based on corporate assessment of the value of the investment, provides centers with a clear measure of the relevance of their longer time-horizon research efforts.

Centers that work with small companies or have contract work in their operation tend to have more short-term research in their portfolio. Examples of some of the balancing strategies used are involving undergraduate and/or postdoctoral research associates on short-term research projects, separation of general center research (long term) and contract research (short term), and obtaining additional direct funding of short-term projects.

5.3.3.2 Avoiding Conflicts of Interest

NSF policy limits the involvement of ERC faculty and staff members in positions of responsibility in member companies or, conversely, involvement of ERC member company personnel in decision-making roles in ERCs. The following is the National Science Foundation's "Engineering Research Centers Program Statement on Conflict of Interest in Technology Transfer on the Dual Role of Center Faculty in an Industrial Capacity":

> *It is generally recognized that technology transfer may be enhanced when ERC faculty or students spin off start-up companies. A conflict-of-interest situation may occur when ERC personnel, including those from the lead university and any core partner universities, have outside interests in companies—financial or otherwise—that may be affected by ERC activities. This applies whether the company is a member of the ERC or not, as long as the company's interests fall within the field of the ERC's technical focus. ERC personnel should exercise the*

> *greatest care and sensitivity so as not to give the impression that public funds are being used to enhance the private income of faculty and students supported by the ERC, or to deter participation by other industrial partners in the ERC.*
>
> *In accordance with Article 33, "Investigator Financial Disclosure Policy," of the General Conditions, which incorporates by reference Section 510 of NSF's Grant Policy Manual (GPM 510), Principal Investigators (Center Directors), Co-PIs and any other Key Personnel who are responsible for the design, conduct or reporting of NSF-funded research are required to disclose to their universities any significant financial interest (exceeding $10,000 in salary, other payments for services, intellectual property rights, or equity interests) that would reasonably appear to be affected by NSF-funded research. In addition to the Center Director, this would also apply to the Deputy or Associate Director(s), Thrust Leaders, and individual PIs working in the Center who carry out the above functions. GPM 510 also requires Awardees to have a written and enforced conflict-of-interest policy and to submit the required certifications as a condition of future funding increments.*

NSF policy with regard to ERC spin-off companies, if they are members of the ERC, is the same. For nonmember spin-offs, the conflict-of-interest concern applies only to principals of the ERC (Director or Deputy Director, member of the center's Executive Committee, or Thrust Area Leader). Essentially, anyone in decision-making authority over resource allocation within the ERC cannot be a principal of a spin-off company. Again, it is vital to guard against even the appearance of a conflict of interest.

5.3.3.3 Other Federally Funded Joint Ventures

Several centers are participants in other federal programs (e.g., those of DARPA and NIST, such as the Advanced Technology Projects [ATP] program). On balance, most centers see such participation as beneficial. Benefits include the industrial relevance of the work, strong commitment and involvement by industry, and willingness of other universities to work together collaboratively. However, not every center finds these large programs beneficial. Disadvantages include "wicked timetables," volatility of funding (causing dislocation in the amount of technical effort in a given project area), and the negative impact that industrial cost-sharing can have on the direct sponsorship of university research by the same companies, given a fixed company budget for support of university research. (See also Section 5.5.1.4.)

5.3.3.4 Industrial Involvement in Education Programs

Industrialists are involved in center education programs as both receivers and contributors. Several centers have industrially focused short courses, workshops, and seminars and industrial degree programs that are offered on campus, at professional meetings, or at company sites. As contributors to center education programs, industrialists lecture, teach entire courses (sometimes as team teachers with faculty), serve on thesis committees, work with students on project teams, act as mentors, and support students financially and with internships. The following case study from Clemson University shows the value of industrial involvement in the educational process. (See Chapter 4 of the Best Practices Manual for a more extensive discussion of industrial involvement in ERC education programs.)

CASE STUDY: *The Center for Advanced Engineering Fibers and Films at Clemson University has made effective use of the Research Experience for Undergraduates (REU) program as a means of increasing industrial involvement in the center's education programs. REU projects are developed jointly by faculty members and the center's industrial partners. Industrial researchers co-advise the students on the project. Since meeting the demands of an industry audience is an important part of the program's communications component, the industry advisors provide feedback on the students' research proposals, progress reports, and posters. As part of the project, the students and the academic advisors visit the industrial location to tour the laboratories and meet industrial research scientists.*

5.3.3.5 Measuring Program Effectiveness

Metrics used to assess the effectiveness of the industrial collaboration/technology transfer program vary among the different centers. Some metrics are required by NSF in the ERC's annual report. Others will be useful in reporting to the center's Industrial Advisory Board. Still others may be used only internally, for program management and improvement. All centers should keep track of the impacts of their work on companies—what was adopted, how it was used, the impact on the company, on the industry, and other indicators. Data quantifying the impact are especially powerful. In all cases, good "nuggets" describing the impact on industry are useful in explaining the center's accomplishments and should be preserved to expand on the numerical listings. In addition to the center’s own use, this information is used by NSF for a variety of purposes.

Metrics used in existing centers include: number of joint research projects with industry; number and names of students hired by member companies; number and titles of publications; number of patents/licenses; company funding figures; in-kind corporate contributions; number and names of companies attending center meetings; number and names of industrial collaborators on projects; number of faculty visits to companies; etc. Some centers have found it useful to individualize the data by company to support center industrial representatives in their justification of membership renewal, if requested.

In assessing its performance, each ERC is required to assess its strengths, weaknesses, opportunities and threats in a specified, structured manner. This SWOT analysis is a vital tool for the center in its efforts toward continuous improvement. It is also among NSF’s most important measures of the centers’ performance

Each ERC’s industrial members perform a SWOT analysis in conjunction with the NSF site visit. Its purpose is to:

- Analyze the *strengths* and *weaknesses* of the ERC's vision, strategic plan, research, education, industrial collaboration, leadership and team, and management system.
- Identify any *opportunities* missed by the ERC.
- Determine if any weaknesses are serious *threats* to the ERC's ability to fulfill its vision.

They summarize the results of the analysis in bulleted slide presentations, for the use of the NSF annual review team and the ERC.

This exercise provides an integrative forum for industry members to focus on center goals; builds more cohesive industry support; provides focused input to the ERC and to the NSF site visitors to help strengthen the ERC; and strengthens the investment partnership between NSF and industry by clarifying industry's priorities and concerns. The center's NSF Program Director also participates in the meeting, briefing industry on the overall ERC Program and the SWOT analysis process.

Each center's students perform a second, parallel SWOT analysis. Members of the ERC's Student Leadership Council gather and synthesize input from participating students (as both workers in and customers of the ERC). Students use the same criteria and techniques as those of the industry members' SWOT analyses, analyzing the strengths of the ERC in fulfilling its vision; determining weaknesses; identifying any opportunities missed by the ERC; and determining whether any of the weaknesses are serious threats to the ERC's ability to fulfill its vision. Like their industrial counterparts, they communicate the analysis to the NSF site review team and the ERC's leadership for the purpose of continuous improvement

A final note on technology utilization metrics: Licenses are an easily measured record of success. Perhaps a more significant cumulative impact, however, is gained from the little ideas and bits of information that spark an inspiration for someone, and when they take it back to their company it becomes an unmeasurable (but important) piece of some large system. One way to measure this is through testimony by working engineers within the company who have benefited from the interaction. Thus, perhaps another metric should be, "Has the center established an effective forum for intellectual exchange within its technology focus area?"

5.3.3.6 Benefits to the Center of Industrial Involvement

In addition to the funding, strategic guidance, and personnel-exchange benefits discussed earlier in this section, centers report nearly unanimously that industry also brings an understanding of what research is relevant. An understanding of the technical direction and needs of the industry is an essential element of systems-oriented, interdisciplinary research and helps provide students with an engineering systems perspective. ERCs develop an awareness of which research is relevant through a variety of means, including Industrial Advisory Board meetings, people exchanges, visits to and by industry, one-on-one research collaborations, technical conferences and reviews, and ongoing technical interactions.

Benefits of industrial participation also include student mentoring through formal and informal research collaborations, student internships, and membership on student education committees. In addition, industry provides input on curricula, so that the education offered reflects industry needs; quality student employment opportunities, both full-time and part-time; research equipment, devices, and materials; help with equipment operating problems; access to industrial facilities for specialized testing; management experience and advice; assistance in obtaining funding from federal programs; and support in site visits with the NSF. Among the benefits are faster commercialization and the ability to do research in areas in which member companies do not have technical strengths.

Interaction with the leading companies in the industry increases the center's credibility and prominence in the field, and can be very instrumental in attracting other companies to become members. This advantage is even stronger when existing members are willing to network actively with the center and prospective member companies.

For ERCs involved in emerging technology areas, the critical mass represented by the industrial members actually nucleates and creates new industries as companies, by incorporating the technologies, give them higher visibility. The center thus grows along with the industry and becomes centrally associated with it.

For a discussion of the benefits to industry, see Section 5.5.1.

5.3.4 Lessons Learned: Building the Constituency

- Company recruitment strategies should be tailored to each prospect; prospective members can be "seduced" into partnership with the center only when an appropriate confluence of interests exists.
- Bad research cannot be sold with public relations. Even world-class research with aggressive technical goals must be relevant to industrial needs or it will not attract the attention of industry.
- Recruiting nontraditional partners (government laboratories, state agencies, small start-up firms, and consortia) requires that the center understand clearly how all parties can benefit from the collaboration and clearly communicate those benefits.
- You cannot have too many contacts or contact them too often; personal contacts and visits are very effective.
- Industry's presence has changed education—universities and industry now share a responsibility to create effective engineering leaders for the future.
- Industry's short-term needs must be addressed without disrupting the educational process.
- Industrial researchers enjoy interacting with students.
- It is important to have champions for the center's program in each company. They do the internal persuasion and make the connections that keep the center well anchored with its members.

- Academic and industrial cultures are very different, especially in time scales, attitudes toward deliverables, and perceptions of problems. This is true even in the oldest ERCs, after 11 years of partnership.
- Mechanisms that foster one-on-one interaction (such as personnel exchanges and joint research) are the most effective way to enhance industrial interactions.
- Many faculty members enjoy, and most benefit from, the synergy of collaborative research with industry.
- Networking of ERC faculty with industry professionals via professional society activities, consulting, invited seminars, and other means is valuable.
- To gain the confidence of the industry, centers must be able to prove concepts and provide solutions, rather than simply produce technical papers.
- Strong industry critiques of the centers' research and education programs—and even their management—are useful; industry may even have formal channels for input into centers' strategic planning and the SWOT analysis required by NSF.
- Routine mailings need to be automated and delegated for maximum cost-effectiveness and minimum impact on management workloads.
- As a center matures, it undergoes a transition from informal to more formal interactions with industry; communications and meetings need to reflect that shift when it occurs.
- Metrics for assessing the effectiveness of the industrial collaboration and technology transfer program are vital and have many uses.

5.4 INTELLECTUAL PROPERTY AND COMMERCIALIZATION

5.4.1 Overview

The major objectives of the ERC program include both developing and commercializing technologies to bolster the competitiveness of U.S. industry. To successfully bridge the gap between technology development and commercialization, ERCs must take a holistic, integrated approach to technology (creation, experimentation, development, and implementation) that is unique among NSF-funded organizations. The involvement of industry representatives in goal setting, project review, technology evaluation, and technology implementation is vital to the success of this effort. In addition, if they are to be successful at commercialization, they must have ways to ensure the equitable treatment and ownership of intellectual property (IP) resulting from research by individual researchers, the ERC, the university, and industry sponsors.

Technology commercialization at ERCs is a relatively new yet rapidly expanding art. The process is significantly more complex than it is where technology is developed and commercialized wholly within a single company or at a small business spin-off based on a university invention. The challenge lies in melding a commercially promising research agenda with the often disparate goals of individual industrial sponsors, guiding the resulting work to a point at which industry can use the product, and supporting the commercialization effort through continued close contact between ERC researchers and industry representatives. Both university investigators and industry scientists must understand that their roles will change from advisor to project director as a commercialization effort moves forward.

These challenges are significant, but ERCs are well positioned to take advantage of the considerable experience of industry in generating value from new ideas. The ERC model has a built-in mechanism for maintaining industrial relevance, in the form of periodic project reviews and direction by industry representatives. Because most ERCs are relatively new to technology commercialization, there are few examples so far of directly commercializable technologies that have emerged from their pipelines (although there are some significant ones) . More common is the transfer of ideas, which industry can refine and cultivate into saleable products. Whether such an idea is protected by patent or license depends on the extent to which the ERC or the industry sponsor developed the idea.

Because the potential for commercial success of ideas is difficult to forecast or control, it is important that ERCs and industry forge a more fluid relationship with university administration concerning ownership rights to intellectual property (IP). For industry, one of the main attractions of belonging to an ERC is the potential access to breaking technology that could bring competitive advantage. Indeed, this is the central purpose of the ERC. The role of the university patent office in maintaining strict control of ownership to this technology must be redefined to reflect the considerable financial and intellectual contributions that industry makes to the knowledge acquisition process.

5.4.2 Product Development and Commercialization

In fundamental research, a full understanding of the impacts and ramifications of the work is impossible at the outset. Industry, on the other hand, requires some projected future payoff to justify research funding. Bridging this dichotomy is at the core of the ERC mission. Of course, not all ERC research will result directly in a commercially viable discovery or technology; however, the likelihood of this result is increased by the periodic involvement of industry at critical points in the research planning and review process. This review process is akin to the product development model, which industry has used for many years. Applying this model to university-based research necessarily involves scaling back such things as market reviews and surveys as hurdles that a new idea must clear. What is useful about the model is the scheduled interaction among various stakeholder groups at critical points in the development (research) process.

5.4.2.1 Developing and Maintaining an Industry-Relevant Research Agenda

Developing the research agenda is a fundamental aspect of ERC management and oversight. However, the perspective of industry has traditionally been absent from this process in university research. It is essential that the ERC's research management team recognize the importance of industrial input, consider the opinions of industry representatives in their decisions, and encourage the research faculty and staff to do likewise.

Most ERCs have established mechanisms for including industrial input in formulating new research and overseeing ongoing work. Most often, this opportunity occurs during an annual or semi-annual meeting of the entire industrial members group or some subgroup thereof. Depending on the diversity of interests among this group, research focus meetings can be held during plenary sessions of the meeting or in industry-specific breakout sessions with only those representatives interested in a particular topic in attendance. For projects sponsored by a single member or a consortium of members, only contributors to the project under consideration need attend.

The diversity of interests among members can make a group meeting of them and ERC researchers a challenge in agenda-setting. Keeping these meetings focused on the goal of developing a consensus in the research direction is vital. Time should be set aside for constructive criticism of past work and decisions, if appropriate; but it is the role of the ERC research management team to keep the meetings on track and focused on setting realistic goals that are likely to produce tangible benefits to industry.

5.4.2.2 The Changing Roles of Academic and Industry Researchers in Commercialization

As the technology developed in a research project moves from the laboratory to the field, the roles of the project director at the ERC and the industrial sponsor will likely reverse. The ERC researcher at this point moves from directing the project into the advisory role, which had been occupied by the industry representative, and vice versa. In some cases responsibility for scaling up the technology may move to someone in industry who had not been connected to its laboratory development. In either case, the ERC researcher should seek to remain available and involved. In cases in which the ERC researcher has a financial interest in the commercial success of the technology (such as partial ownership of the IP), the incentive for involvement is obvious. The importance of input from the researcher in maximizing the chances of success of the technology (regardless of IP ownership) should not be overlooked, however.

5.4.2.3 Balancing the Needs of Researchers and Industry

Throughout the commercialization process, it is important to balance the needs of industry and the university. Where a university's central missions are teaching and generating knowledge though research and publication, industry is concerned with maximizing financial value. The potential for conflict between the two must be acknowledged and dealt with in a balanced manner. Questions about the nature of confidential information, the length of time a discovery must remain confidential, and how results can eventually be published are usually specifically addressed in the research contract and confidentiality agreement. The terms of these documents are usually negotiated among the ERC, industry legal staff, and the university technology transfer office.

5.4.2.4 Using Commercialization Successes as a Marketing Tool

Successfully commercialized technologies are valuable tools in marketing the ERC to prospective members. To the extent that technological advances cross industry lines, a new process or idea may enhance the appeal of ERC membership to previously underrepresented industries. The ongoing process of market analysis for new membership should constantly evaluate the appeal of new technologies to potential sponsors.

5.4.3 Intellectual Property Rights and Ownership

The treatment of IP generated through industrially funded university research is one of the most challenging and potentially time-consuming issues facing ERC staff. Traditionally, universities in the United States have tightly held ownership rights to intellectual property generated by university research. As company-sponsored research has increased dramatically at universities in recent years, the equity of this policy has been challenged, particularly at universities with institutionalized industry-funding programs such as ERCs. While outright ownership of IP is usually reserved for companies that both give generously to the general research program at the ERC and sponsor individual projects, access to IP through licensing has much broader potential for ERC member companies. An added complexity for ERCs is the formulation of policies to equitably distribute IP and/or licensing rights from research funded by consortia of companies. To avoid misunderstandings and legal problems, policies concerning IP must be explicit in the ERC charter and membership agreement and must be understood by sponsors. These policies are typically negotiated with university administration in an ongoing process, to meet new situations.

5.4.3.1 Agreement with University Administration

All centers work with their university intellectual property officers to comply with university standards on such matters. One now-graduated center (Lehigh's ATLSS center) established a spin-off company partially owned by the university to handle IP issues. A good working relationship with the university IP administrators is important in developing a successful partnership with companies. If a center spans more than one university, clear agreement among the administrations of all the academic partners is essential. Procedures for notifying members of the existence of center-developed IP should be clarified between the center and the university's intellectual property officer. In all cases, IP agreements should accord with regular NSF guidelines, as set forth in NSF Grant Policy Manual 95-26.

A related issue is distribution of royalty income. Most centers use their university's defined split (usually 50-50) between inventor and administrative units. Whether the center negotiates to be part of that split is another important early-stage decision. If the center is not included in the formula, the director can approach the university administration and/or technology transfer office and negotiate a portion of future royalty returns to be earmarked for the center. Because there is no "money on the table" during these negotiations, it may be possible to secure a future revenue stream before the center even begins its research. Taking a long-term view toward self-sufficiency for the center, it is a good idea to be in on that split.

Some ERCs have negotiated more favorable terms with university administration. The Marine Bioproducts Engineering Center (MarBEC, at the University of Hawaii), for example, receives 100% of the university's share of the first $10 million in IP revenue generated from a patent. In addition, MarBEC has arranged for the return of 17% of licensing fees to the ERC. In negotiating such terms, it is helpful to seize the moment when the ERC is funded, to take advantage of the excitement and support generated by the NSF grant to gain IP concessions from the university. However, such IP policies may make it difficult to partner with other universities that may not accept these terms.

5.4.3.2 *Membership Levels and IP Rights*

Many ERCs have developed "tiered" approaches to industrial associate membership, wherein companies may opt to increase their access to IP or licensing rights on projects they fund in addition to their membership dues in exchange for higher annual dues. The advantages of this system are that the ERC obtains increased annual funding based on the expected future value of IP and/or licensing rights. The details of the tiered membership system must be formulated in concert with the university technology transfer office and existing or prospective members.

The membership system in multi-institutional ERCs presents an added level of complexity. Here, membership rights often reflect the least common denominator. For example, one university may be able to offer companies better access to intellectual property than other universities in the center can. But it is important for the center to present a single criterion of industry benefits, reflecting the consensus of all the partner institutions. Variations can be addressed internally, so as not to confuse the member companies. It is therefore imperative that negotiations between the multiple institutions of the center be started as early as possible, because the development of an agreement suitable for all institutions can be very time-consuming. Once the institutions have agreed upon the center's IP policy, a memorandum of agreement (MOA) should be developed and signed by all member institutions for documentation and reference.

CASE STUDY: *Membership rights and intellectual property management vary widely from center to center, reflecting the customs of the universities and industries involved. UWEB has a single membership status and a single membership fee. However, early joiners received a substantially discounted founder rate by joining during the center's first two years, while late joiners (after the first five years) are subject to substantially higher fees. These fees are the same otherwise, regardless of the size of the company.*

Although larger companies enjoy a substantial advantage from the single fee schedule, this structure enabled UWEB to enroll a total of 33 members in its first two years, with a stable core of about 25 that have maintained continuous memberships for the life of the consortium. Their long-term sponsorship has let UWEB develop a cohesive and interactive stable of participants. It also helps attract new sponsors, despite the higher fees charged in later years. The core group has supported UWEB as it built a track record of industrial productivity as testimony to encourage new memberships. The detriment to smaller companies is compounded by this fee structure, and only large corporations are expected to become sponsors in the later years of UWEB. However, several small organizations have belonged since the first two years, and UWEB accommodates them in other ways, especially sharing the costs of industry initiatives such as Small Business Innovation Research (SBIR) grants and National Institutes of Health (NIH) Bioengineering Partnership Grants. These other sources of leveraged funding are of great benefit to the companies and to the university.

Another aspect of UWEB's "one size fits all" approach to sponsorship are the intellectual property rights enjoyed by all sponsors. Small companies enjoy the same IP rights as large ones. This is of definite benefit to the smaller companies. Although some ERCs that have multi-tiered membership structures allow much lower rates for small companies, they do so by removing some or all IP access. While doing so is acceptable in some industries, it was deemed inappropriate at UWEB, most of whose members are in the medical device and medical diagnostics industries.

The business models of small, highly entrepreneurial companies tend to rely on capture and control of intellectual property, especially in the biotechnology and biomedical areas. Many such companies are founded on exclusive ownership of their core technologies, by either invention or license; shared access and shortages of resources *combine to make participating in R&D consortia difficult for them. Still, small companies often can act quickly to adopt fundamentally new technology. Therefore, the best chance for involving these firms is with highly fundamental IP, which start-ups are more inclined to tackle at the earliest stages. UWEB has found that its larger sponsors (5,000-10,000 employees and $1-10 billion in revenues) capitalize on fundamental discoveries in only a handful of cases in which a powerful discovery directly affects their product lines. Such cases are maintained for use in the consortium, while the more ancillary, fundamental inventions that have a less-obvious commercial application are cleared through the consortium for small companies and spin-offs to adopt.*

Nevertheless, the ideal model for an R&D consortium is for members to share all IP equally on a nonexclusive basis. Furthermore, a paid-up commercial license for any technology would most easily be distributed by having the membership fee be substantially higher to accommodate a return on the ERC's investment. With a high enough fee, even royalty-free, paid-up, nonexclusive commercial licenses can be designed so that the fee structure makes the entire program self-sufficient.

However, such models are inappropriate in the biomedical arena, and most universities shun them. There are cases in which a "big hit" could end up being given away for the same price as less substantial inventions. In reality, it is the substantial margin from the sum of all the "little hits" that offsets any "giveaways." Although the math is easy to calculate, many universities—especially state-sponsored ones—are restricted from playing this fast and loose with state assets. The officials of any university are subject to great criticism, and although the rights to cold-fusion, for example, couldn't be given away for free today, in 1989 substantial sums of money were being considered.

To balance these forces, UWEB adopted its uniform-fee policy. Early joiners also stand to benefit from securing IP rights as they evolve from the launch of the consortium, and some of the most prominent licensing activities at UWEB stem from the first round of projects funded. UWEB is able to keep the company interest separate, and any company can seek an exclusive commercial license. Restricting the license to narrow product categories separates these interests. If one or more companies want to license the same invention for the same product categories, then the University of Washington (UW) will grant them commercial license on a co-exclusive basis. In such cases the UW agrees not to allow other companies to license the invention for this purpose. (UWEB's IP system is outlined more fully in Section 5.4.3.4.)

Where does UWEB fit on the spectrum of ERC IP architecture? Two points are critical. First, it is a "closed club," in which access to research and intellectual property is for sponsors only. The UW, in the UWEB Sponsorship Agreement (which is identical for every sponsor organization), requires that that all companies performing research within the scope of the UWEB Consortium must become sponsors. Eventually, the research is always published, but sponsors have early access and first rights of refusal for all IP. Although any company or research organization is invited to join the ERC at any time, only sponsors receive the technology alerts, invitations to the annual Industry Symposium, and special publications, including immediate access to the annual report to

NSF and all final and interim UWEB project reports. This arrangement is unusual, but is highly attractive to the biomedical companies that join UWEB.

Second, UWEB's efforts in patent management are also at the far end of the spectrum for ERCs. It is considered essential that the consortium control its own destiny as much as possible. Such control would have been difficult to attain without proven success over two or three years using a step-wise and measured approach. The UWEB model is currently being adopted for new R&D consortia at UW—fortifying further the mission of ERCs to have a major impact on the university culture.

5.4.3.3 IP in Relation to Funding Source

Treatment of IP rights varies depending on the source of the funds that generated that research.

- Core ERC Research—

As with most university intellectual property, IP generated from ERC core research is not normally subject to ownership by industry, although industrial members may enjoy preferential licensing rights to this technology over non-associate companies. Industrial associates may enjoy the right of first refusal on licensing or may receive a discount in royalty fees compared with non-associate companies for IP generated from ERC core research. It is important in working with core IP that all members be treated equally in the licensing process.

- Research Funded by a Single Company—

IP resulting from research funded by a single company may be subject to partial (or full) ownership by the sponsoring company, depending on prior agreement between the ERC, the university administration, and the company. Some ERCs confer ownership of IP from sponsored research to the sponsoring industrial associate member based on a premium level of membership (see Section 5.4.3.2). In other cases, the magnitude of the sponsored project may entice the university to partially relinquish IP ownership. Another option here is for the university to retain IP ownership but grant a free (or reduced cost) license to the sponsor for use of the technology.

Another option with emerging technology is to grant a non-commercial site license to a sponsor in order that the technology may be further proven in an unaffiliated lab.

- Research Funded by a Consortium of Companies—

IP ownership and licensing rights are further complicated by the involvement of several companies (a subset of members) in funding work as a consortium. An important distinction to note is that these consortia are funding a project in addition to paying normal membership dues to the ERC. In this case, it is crucial that all members of the consortium have equal access to the technology and equal rights for IP ownership or use through licensing. Contractually, it may be most expedient to execute separate though identical contracts with each company, acknowledging the involvement of other companies that in many cases will be their competitors. A model for equitable treatment of companies is presented in the following subsection.

5.4.3.4 A Model for IP Technology Transfer

The University of Washington Engineered Biomaterials (UWEB) center has formalized a model for technology transfer among their industrial associates group, as outlined in the following case study.

CASE STUDY: *Technology transfer at UWEB follows the "Technology Alert" system. The process begins with the internal filing, by a UWEB investigator, of an invention disclosure with the university's Office of Technology Transfer. This document is authenticated to verify the source of funding and the identity of inventors. A confidential summary, describing each invention, and a short description of its background and potential use is sent simultaneously by courier to each UWEB sponsor.*

Sponsors are presented with such UWEB Technology Alerts several times a year. They must sign an Election to Obtain a License for any and all inventions disclosed to them in which they may be interested. These elections are not binding on the company, but if a company fails to elect in the required period (three months), it relinquishes any rights of refusal they have to that invention as UWEB sponsors in good standing. During and after this window of opportunity, the sponsors are notified, without identifying the electing companies, if other sponsors have elected to obtain a license with a complete summary after the close of the window. All first rights are managed through this election process.

Following the elections, the follow-up time is variable, depending on the maturity of the invention. If the research is fairly complete, then all sponsors that have elected to pursue the technology are presented with an Option Agreement to sign, which legally secures there interest and commits them to commercial development. These options are renewable for a second year, by which time commercial licenses are to be signed to maintain the sponsor's rights. If further research is needed at UWEB to bring the invention to a level of clarity or reduction to practice, then option agreements are delayed. Any company at any time may enter into a noncommercial site license, for use of a UWEB invention for internal research, and most do so at the time that option agreements are secured. Other companies forego commercial licensing rights and enter solely into noncommercial site licenses at standard rates, even though they "passed" on their first rights of refusal, and cannot later use the invention for commercial purposes. Overall, the key to this complex solution to a difficult set of issues is to provide flexibility and exclusivity as desired and needed by the sponsors.

UWEB's IP management strategy involves challenging and even changing the culture at the university. The University is consistently ranked high in the nation for capturing IP revenue. Although its systems for technology transfer are mature by any standards, the management of licensing in an ERC posed a substantial challenge to the UW also. What has evolved is based on the general principle that "What's good for UWEB is good for *the UW." With this starting point, it became necessary for the UW to grant greater control of patenting to the ERC itself, with a full return of costs and a share of revenues. The principle is simple, but coming to terms with the university required some years of operation. UWEB's technology alert system was a new step at the UW, and once it acquired a proven track record it allowed the ERC to negotiate with the UW. The next step was to establish a patenting system that was under the control of UWEB. UWEB sponsorship fees are used, in part, to pay for patenting inventions from UWEB-supported projects. Decisions about expenditure of these monies are the responsibility of a Patenting Review Committee that makes recommendations to the UW. This committee consists of four members of the industrial advisory board, two members of the UW Office of Technology Transfer, and the UWEB Director of Industry Relations.*

In this way, the UW has direct industrial input into its patenting decisions. Over time, this relationship between the UW and UWEB has acquired a proven track record. The final step in the ERC-UW relationship is the negotiation of the sharing of excess revenue, beyond cost recovery for patenting. This revenue is derived from licensing fees and royalties. With this system, the capture of IP revenue is expected to become an important component of UWEB's self-sufficiency model. To minimize risk, the recovery of patenting costs is expected to be complete for a given invention following the signing of option agreements, regardless of actual product development.

5.4.4 Patenting

Due to the significant costs involved in applying for patent protection for IP, most universities have full-time staff and/or a committee that decides if an idea, design, or process is worthy of patent application. Committees of this kind may include university administration, legal staff, ERC research staff, and the ERC industrial liaison officer. At some ERC universities, patent application costs are paid through sponsorship dues. This approach guarantees that adequate funding will be available to pursue patents on worthy IP before the generation of any royalties or licensing fees. Obviously, such receipts should replenish this account when they become available.

In determining the merit of an idea, process, or potential product, the advice of the university technology transfer office should be sought early in the process. Disclosure of the IP at the earliest possible date is important in establishing and protecting the rights of the inventor and university.

5.4.5 Lessons Learned: Intellectual Property and Commercialization

- A significant reason many companies become ERC industrial members is the potential for early access to valuable ideas and/or processes. ERCs must recognize this value and provide equitable access to technology for members.
- The development of commercially valuable technologies is enhanced by close cooperation of ERC researchers and industry representatives. Early and periodic involvement of industry in setting and refining the research agenda is important.

- ERC researchers should remain involved in commercialization efforts even after the technology has been handed over to industry.
- The needs of university faculty to publish and the needs of industry to maintain confidentiality are frequently at odds. The details of confidentiality periods and publication must be specified in the research or membership contract.
- There are many approaches to sharing IP ownership among inventors, the university, and companies (sponsors). It is important to work with all stakeholders to arrive at an equitable agreement that is well understood by all participants, and that includes the ERC as the originating unit.
- It is wise to negotiate special overhead rates on memberships and royalty revenue splits with the proper university administrators in the early weeks of the center, while enthusiasm for the center is high.
- In multi-university ERCs, discussions leading to the development of an IP arrangement suitable for all partner institutions should begin as early as possible.
- Much of the knowledge developed at an ERC is not appropriate for intellectual property protection. However, with early access to this knowledge and the opportunity to influence the direction of fundamental research at the ERC, members have many opportunities to implement this knowledge into leveraging their R&D and commercial developments. Thus, without the obvious tracking of commercial development through licensing of intellectual property, ERCs must struggle to document the flow of knowledge into the U.S. technical markets. Testimonials and other evidence for this knowledge-to-market flow are important for an ERC to track and understand in order to validate the success of the ERC model.

5.5 BENEFITS AND DIFFICULTIES FOR INDUSTRY OF INTERACTING WITH ERCs

5.5.1 Industrial Benefits of Membership

Industrial sponsors of ERCs generally feel very positive about the contributions of the center to their industries. Many companies see the centers as critical components of their industries' research and educational development.

5.5.1.1 NSF Study of ERC-Industry Interactions

In FY 1996, NSF's EEC Division completed a study of ERC-industry interactions.[*] Its purposes were to (a) examine patterns of interaction that have emerged between ERCs and industry, (b) determine which types of interaction were most useful to industry, and (c) assess the value and impacts of interaction to the companies. Nearly 90% of industry sponsors determined that their firms had received benefits from ERC participation, and about two-thirds indicated that the participation had had at least some effect on their firms' competitiveness. Of those reporting an impact on corporate competitiveness, four in ten rated the impact of ERC participation on their competitiveness as "moderate" to "a great deal."

The major benefits fell into five categories: (a) access to new ideas, know-how, or technologies; (b) technical assistance; (c) interactions with other firms participating in the ERC; (d) access to ERC equipment and facilities; and (e) access to ERC students and graduates as potential employees. Only 40% of representatives' firms had hired students or graduates; however, those doing so valued this result of ERC interaction more highly than any others. While a small proportion of firms received benefits associated directly with intellectual property, these benefits were valued more highly by the firms than any other type of benefit except those associated with hiring ERC students and graduates. (Section 5.4, "Intellectual Property and Commercialization," reviews some of the ways ERCs manage intellectual property.) Many firms benefited in ways that they had not anticipated when first joining. Breadth of opportunity for benefits was, therefore, an important factor in firms' experiencing benefits from involvement with ERCs.

Perhaps the most important result of the study is that companies receive benefits in direct relation to the number of years they participate in an ERC and the extent of active involvement with the center: the longer firms participated and the more direct personal interaction there was between corporate and center personnel, the more direct benefits the firms had received thus far and the greater the effect on company competitiveness. Firms expecting specific benefits in the near future often planned to become more involved with the center through such things as personnel exchanges and joint projects in order to realize the expected results. Involving more corporate personnel in center activities than just the firm's ERC representative was a key to firms benefiting from ERC participation.

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[*] Reported in *The Engineering Research Centers (ERC) Program: An Assessment of Benefits and Outcomes (NSF 9840).* National Science Foundation: Arlington, VA, December 1997.

5.5.1.2 Benefits as Identified by Industrial Liaison Officers

Industrial Liaison Officers describe the main benefits of center membership for industrial sponsors in much the same way as industrial members do in the study just described. The Industrial Liaison Officers list these benefits (in priority order) as:

- Early access to highly leveraged cutting-edge research results not achievable in individual companies
- Access to a steady supply of graduates skilled in the newest technological approaches and in interdisciplinary systems thinking and with strong industrial orientation (since 25–95% of center graduates go to sponsoring companies)
- Recruitment of top students into the field
- Interaction with other companies at a personal and technical level that would otherwise not be possible
- Maintenance of research project continuity over extended periods of time
- Use of ERC-developed specialized equipment for characterizing and evaluating research concepts designed to address industrial problems.

Other important benefits identified are preferential access to specialized facilities and equipment, access to faculty members, training for industrial researchers, influence on research directions in the center, and participation in workshops, seminars, and research review meetings.

CASE STUDY: *UWEB corporate sponsors' views of the benefits of membership correlate highly with the list above, compiled from Industrial Liaison Officers. Most company participants are scientists, engineers, and technical managers. They are attracted mainly by the high caliber of the science and investigators at the ERC. Also high on their list is the interaction with and opportunity to hire the students in the program.*

However, it is important to note that these are not the primary benefits that these personnel report to the upper management of their companies. The chief benefit by which they justify the annual costs of UWEB sponsorship is technology transfer and the chance for the company to secure IP for future product development. There are a handful of upper management individuals who regularly attend UWEB events, and their support is absolutely essential (particularly in the very large companies that have numerous divisions and employee rosters in the tens of thousands).

One way to raise the profile of the ERC among its corporate sponsors is to encourage the technical personnel in corporate divisions to move sponsorship fee onto their companies' corporate budget. This move has benefits for both the division and central levels of a company, and for the ERC itself. While technical personnel are learning through their participation, the corporate leaders are able to keep an eye out for advancing technology. Surprisingly, UWEB has even been able to play a role in enhancing the communication between divisions of some of its sponsors through the establishment of joint projects requiring the cooperation of personnel in both the divisions and headquarters.

5.5.1.3 Job Performance of ERC Graduates

A second NSF-sponsored study of ERCs, also completed in FY 1996 and reported in the 1997 NSF report noted earlier, examined: (a) the extent to which masters and doctoral graduates with substantial ERC experience are more effective on the job than their peers; (b) what the graduates did while at an ERC; and (c) the impact of ERC activities on the graduates' effectiveness on the job. While the emphasis was on those who were employed in industry, those working in academia and those in Federal or other sectors were included.

ERCs give students broader, non-technical capabilities that make them more effective as potential leaders in industry and elsewhere. Supervisors and corporate representatives value these capabilities, and graduates identify ERCs' impact as strongest in these areas as well.

The ERC culture of interdisciplinary teams, research relevant to industry, and direct involvement of industry produces these results in students, but each ERC still needs to improve its impact on students. Graduates judge their performance in these areas as just slightly better than that of their peers, yet see themselves as clearly superior in numerous technical areas. They recommend that ERCs expand significantly the exposure of students to industry, especially through internships. Long-term involvement in teams with industrial researchers is also necessary to broaden the students' experiences and capabilities in the areas that make them most effective in industry.

Ultimately, corporate partners and students will benefit most from greater involvement of corporate staff in ERC activities. More is better" is the main message of these studies. ERCs that approach their interactions with industry and graduate education from this perspective will go a long way toward ensuring that firms and students benefit from the ERC culture to the greatest extent possible.

This study of the effectiveness of ERC graduates is summarized in greater detail in an attachment to Chapter 4, "Education Programs."

5.5.1.4 Benefits of University Consortia

In some centers, another benefit to industry has been the opportunity to leverage the research and educational capabilities of more than one university. Some of them, such as the Center for Emerging Cardiovascular Technology (a graduated ERC) at Duke and four other universities, have formal academic consortia (described in the following case study). Others leverage their faculty effectiveness and enhance their credibility with industry by collaborating with colleagues at other institutions, either formally as co-PIs or informally. One center worked with its university's school of business, developing a joint proposal to help companies with both R&D and marketing the technologies of the ERC. Centers have collaborated with other universities on proposals for other (non-ERC) federally sponsored research and in order to form strong bases for significant contract research. Interaction of universities is vital in some centers' education programs, as illustrated in the case study that follows.

CASE STUDY: *The recently graduated Center for Emerging Cardiovascular Technology (CECT) integrates the capabilities of three North Carolina universities, Case Western Reserve University, and the University of Alabama. Each brought to the center a unique expertise or resource that was important to the ERC's goals. The center found this university consortium structure to be both rewarding and a major obstacle. On the plus side, the multi-university nature of the center increased the ERC's appeal to industry, providing complementary expertise and resources, and thus significantly greater research capabilities than any of the universities in the center could offer themselves. Communication among the various faculties and student bodies was enhanced by quarterly retreats to review progress and strategic plans.*

On the negative side, the center faced the conflict, for faculty members, between supporting the ERC and supporting their home universities. Since faculty members receive recognition for bringing research contracts into their home departments, their contributions are not always clear to their home university when contracts or grants are negotiated and awarded through the ERC, even though they may be contributing significantly to both the university and the ERC. All ERCs face this problem, but it is magnified in the multi-university context. The CECT has not found a solution to this problem that does not compromise the synergy and joint focus that a center provides. Another complex issue is intellectual property management. In joint projects, the issues of who owns what and how the royalties are divided take an immense effort to resolve, particularly in dealing with a mix of public and private universities. CECT made progress in this area by negotiating a memorandum of understanding among the institutions that provides a basic agreement on these issues.

Management of IP issues is a widely discussed topic across all the ERCs. (Section 5.4, "Intellectual Property and Commercialization," reviews the best practices in this area.) In the past few years, some of the key challenges, especially for multi-university ERCs and ERCs with subcontract participants, stem from efforts to clarify and establish clear procedures and policies. This issue is manageable, however. In the case of the Center for Power Electronics Systems (CPES), a cooperative agreement among the five affiliate universities was established, with a clear procedure for management of IP. The time required to establish the guidelines was said to be time well spent, and the lesson to be learned is that the ERC must go through these processes.

At UWEB, subcontracts clearly specify that IP derived from the ERC research at the participating institution must be licensed through the ERC to the UWEB sponsors. This provision is necessary to ensure that IP is protected for the sponsors. Otherwise, there is no legal barrier to licensing ERC-funded research to non-ERC participants.

Adopting such policies with multi-university ERCs may not always be easy; procedures must be derived from the policies of each university. It may not always be necessary, or even desirable, to blanket all of the ERC's IP in such fashion. The key issue is to determine what is best for the long-term success of the ERC. In most cases, intellectual property law dictates the disposal of joint IP, and agreements that clearly delineate control of licensing are rationally derived. The lesson to be learned is that it is worth the effort and it is necessary to derive these systems.

5.5.1.5 Benefits in the Form of Spin-off Companies

Many centers report entrepreneurial activity resulting from center research as a benefit to the industries they support. In some cases, an independent entrepreneur works with center technology licenses as the basis for the new venture. Legal issues are handled by the university's intellectual property officers and must conform to agreements in place with the center's member companies. These start-ups sometimes include current faculty participation, so a clear understanding of the university's policies on conflict of interest is critical. (See Section 5.3.3.2 for NSF policy in this area.) In many cases, former students and/or former faculty members participate in the start-up. The following case studies, as well as the example from the Montana ERC that was described in Section 5.3.1.4, illustrate the kinds of entrepreneurial activity being spawned by ERCs.

CASE STUDY: *The Data Storage Systems Center (DSSC) at Carnegie Mellon University has been influential in the establishment of three start-up companies: Ansoft, Phase Metrics, and Advanced Materials Corporation. Ansoft Corporation was founded by a professor and a graduate student from the Center to develop and market computer-aided engineering (CAE) software for simulating magnetic fields. The company employs about 40 people and is the largest corporation in the world dedicated solely to providing CAE software for electromagnetics. Center researchers, in cooperation with Ansoft, have developed a number of advanced computer algorithms for magnetic field simulation as part of the center's continuing efforts to design improved magnetic recording heads. Ansoft has developed a variety of commercial products from these algorithms, based on research conducted at the center, for which the company pays royalties to Carnegie Mellon University. Its software is considered among the most advanced in the industry in terms of the solution procedure employed and the capabilities offered. This technical leadership results directly from the transfer of technology from the Center to Ansoft—a clear demonstration that ERC research can lead directly to useful commercial products.*

In the second case, Phase Metrics, DSSC researchers developed unique instrumentation for measuring the performance of magnetic recording heads using a scanning, small-spot magneto-optic photometer. This invention was the basis for a new line of industrial development. Several sponsors of the center developed systems at their locations using the center's designs. One of the corporate representatives ultimately formed a new venture, Phase Metrics, which now manufactures such systems and sells them to manufacturers of magnetic recording heads.

A third spin-off from the DSSC, Advanced Materials Corporation (AMC), is developing magnetic materials for data storage devices. This start-up employs more than 15 people and is the premier U.S. company in high-energy permanent magnetics and related materials.

CASE STUDY: *The Center for Neuromorphic Systems Engineering (CNSE) is a leading force in supporting entrepreneurial activities and courses at Cal Tech, not only on behalf of its own students but also across the university generally. As a result, CNSE students have founded a number of successful start-up companies. In 1996, two CNSE graduate students started Digital Persona, the company that developed the first consumer-oriented fingerprint recognition system. The idea for the product came out of a class taught by professors Pietro Perona and Demetri Psaltis of the ERC.*

Shortly after the company was established, in 1997, Digital Persona won the Best of Comdex award and since then it has gathered a number of superlative reviews in the technical press, including PC Magazine Editor's Choice Award in 1999.

The company's products—a combination of hardware and software under the trade name "U are U", reads any of the user's fingerprints, at any angle—even upside down. The sensor is designed for ease of use and it requires no power supply. Tens of thousands of units have been sold to date and the product has been incorporated into IBM's desktop computers with the built-in Embedded Security Subsystem. The company has now a world-wide distribution system and approximately 50 employees at its headquarters in Silicon Valley.

realMOVES is another new company, formed by two CNSE graduate students in the Center's Vision Group. The students are the winners of Caltech's second annual $20K Business Plan Competition, initiated by entrepreneur Glen Hightower. realMOVES is developing video capture and software methods that will allow computer characters to move realistically, in real time. The company sees the video and computer games markets as their initial targets.

A third student start-up is Holoplex. This company's goal is to develop holographic memory products. The company designs and builds systems that require the recording of a large number of holograms in all commercially available recording materials (photorefractives and photopolymers). Application areas include image storage and recognition. The company also produces a gesture recognition system applied to a very successful video game product.

Clearly, these case studies demonstrate that ERCs can be very effective in creating start-ups and spin-offs, especially in high-risk areas that are considerably ahead of current industrial interests. Spin-offs often serve as a vehicle for pushing out technology that the more established companies may be reluctant to move forward on. However, not every industry is suitable for this approach. The best consortium model generally is for the ERC to maintain fundamental discoveries and technologies for the use of its members on a nonexclusive basis commercially.

5.5.2 Successes and Difficulties

ERCs are risk-taking organizations. Most assume that if they are not regularly failing at something, then they are not living close enough to the experimental edge. The trick is to learn from the failures and integrate the resulting knowledge into the next attempt. This "change agent" mentality is what both NSF and industry say they want from ERCs; but long-term success through strategic failure is hard to measure and justify. It is a uniqueness of the ERC Program that needs continued nurturing and protection.

Continued maintenance of the company membership base and recruiting of new members is more difficult than it was in the early days of the ERC Program. This is a result of economic stresses in industry and a much stronger desire by industry to ensure that clear, defined benefits result from the funds that are spent for external research. Resource limitation is a problem at universities as well, with faculty time being a prime example. In some centers, no industrial recruiting is done by faculty because they are overloaded. In the absence of strong university rewards for successful recruiting of center members, faculty members choose to spend their time in other pursuits. This disincentive still exists. Other issues perceived as barriers to getting and keeping companies active in centers are:

- Increasing costs of research at universities
- The problems of generic vs. proprietary research
- Publication requirements of universities
- The mismatch between short-term research questions and longer-term graduate education
- Dealing with the imbalance among sponsors' views of desirable long-term research directions
- Ineffective communication with upper-level management in sponsoring companies
- Overuse of the academic paradigm of published results (technical reports, papers) for the industrial audience, which is more attuned to technology application (whether or not the result was actually used to design or build something).

Effective interaction with industrial sponsors is most often limited by the failure of either industry or the center to provide the resources (time and appropriate personnel) for interaction. Partnerships grow best with continuity in the people involved and a commitment to regular communication—again, the health club analogy holds true: "The more you use it, the more you get out of it." It is important for upper management in sponsoring companies to understand that the greatest benefit from membership is the most costly in personnel time. Centers need to provide incentives to faculty members to continue developing partnerships with companies. Some centers report that the key is the reward of the intellectual challenges provided to the faculty member by the company partner; but for this to be effective, the matching of faculty interests and those of the company researcher must be quite close. One center is experimenting with using student time to compensate for the time constraints on both industrial personnel and faculty. A related barrier to effective interaction is travel restriction—the first response of a company to economic stress. Some centers are now using more of their own resources to visit sponsoring companies. The extensive use of email and the growing use of web-based interactions is designed in part to reduce the negative impact of these travel funding constraints.

It is worth noting that one center identified contract research as its chief success while another center identified contract research as its chief failure. It is a cliché, but also true, that any challenge represents an opportunity. And opportunities are just that, possibilities to be actualized in a unique setting. Each center works within its own industrial and university environment and must choose its path, not based on what works elsewhere, but on what may succeed for it.

In addition to these successes and difficulties in the relationship with companies, it is important to recognize that the universities are perhaps the greatest beneficiary of the NSF ERC Program. Today's academic environment is being swept by change in both the quantity and quality of industrial interactions. The ERC provides a challenging yet well-honed paradigm for achieving these goals. Most U.S. universities, despite great success in recent years, are still learning how to work efficiently with industry, and an ERC can lead the way. An ERC stands to benefit greatly as its host university and affiliated institutions continue to regard the ERC system as a trailblazing effort. Some of the chief benefits to the university are:

- If it can successfully conduct one consortium, it can grow to adopt new ones.
- The skills and coordination required to manage a consortium become fundamentally integrated with the disparate departments involved in university administration—especially in coordinating R&D contracts, IP management, and commercial licensing.
- An R& D consortium, built over many years, is an "instant marketing" system comprising a set of well-informed partners (as opposed to a series of one-at-a time and one-to-one handoffs). The consortium partners will tend to "pull on the rope," rather than pushing on it, as most universities do today.
- A well-managed group of targeted R&D consortia can be used to steer the university in new directions and to capitalize on underutilized assets, especially for faculty needing and seeking new research directions.
- For both new faculty and highly successful senior researchers, the consortium model developed along the lines of the ERC system, can lead to greater scientific and technological accomplishment overall. The scientific enterprise in such a highly coordinated, multidisciplinary system is an enormous drawing card to the best scientists. It is venturesome, but accurate, to compare ERC efforts to larger-scale endeavors such as the Manhattan Project or the NASA's Apollo Program. These goals could be met only through a large-scale, interdisciplinary approach, and the excitement of their scope attracted the very best scientific and engineering minds. The goals of revolutionary engineered systems have the same attractiveness—especially for the most successful investigators at any university. Great science and technology attracts the best minds in any setting, and the overall mission of the university is given a quantum leap in scope with these consortium efforts.

5.6 NSF ERC PROGRAM SUPPORT FOR INDUSTRIAL LIAISON

The National Science Foundation is a catalytic partner in each ERC. It selects experimental situations to leverage federal resources with those from industry and other private sources in targeted technology development. This section summarizes the best practices of ERCs in using the NSF relationship to fulfill the industrial liaison function.

5.6.1 Importance of NSF Imprimatur to ERCs

The NSF imprimatur lends credibility to a center. In addition, the opportunity to leverage industrial funds with NSF funds is attractive to sponsors. The tie to NSF also lends support to the center’s pursuit of long-term or basic research. The ERC has an NSF-funded management and operations infrastructure that makes the difference between a mere collection of faculty and an interdisciplinary center with an ambitious mission. In a center that is in start-up mode, the NSF connection is especially critical. Some ERCs report that without the NSF leveraging they would not exist. Others, after NSF support has lapsed, are testing the NSF imprimatur as “graduated” ERCs; some believe they will maintain reasonable industrial support from the established membership, based on their track record and reputation, while others are waiting to see.

5.6.2 NSF Support for Industrial Liaison

An ERC is expected to have an active, long-term partnership with industry and practitioners in planning, research, and education so as to achieve a more effective flow of knowledge into innovation and to help the ERC produce a new breed of engineers. Since the circumstances for each ERC vary greatly, the methods of achieving this expectation are very different. However, there are many similarities across the ERCs, as well as lessons each can learn from the others. Consequently, NSF has created periodic forums in which ERCs can draw on the knowledge and experiences of others. Those of most value to the ERC Industrial Liaison officer are:

- ILO closed sessions and breakout sessions before and during the NSF ERC Program annual meeting (usually in early November)
- Biennial ILO meeting with NSF and industry representatives (every other year)
- ILO consultancy (generally in the first 18 months after a new ERC is established).

The annual and biennial meetings are intended to bring together key people involved in the industrial liaison function from new, existing, and graduated ERCs to promote cross-fertilization, establish networks of contacts, share experiences and insights, and open channels of communication. The consultancy is a team of experienced ILOs who visit new ERCs to provide personalized guidance and insight into establishing more effective industry collaboration and technology transfer.

5.6.3 NSF Program Director Role in Industrial Liaison

To foster an appropriate ERC environment and provide a personal line of communication, NSF assigns each active ERC a Program Director (PD). PDs provide guidance to ERCs based on experience from other situations and technologies. They also play a vital role in communicating the ERC culture and philosophy to industrial affiliates, as discussed further in Section 5.6.4. The following suggestions are provided as ways to build a trusted partnership between NSF, industry, and the ERC:

- Invite the PD to industry meetings to communicate NSF ERC culture and philosophies.
- Invite the PD to industry meetings to communicate feedback from site visit reports on items of specific importance to industry.
- Encourage industry to communicate directly with the PD if there are pressing issues, both positive and negative.
- Although preparing the industry SWOT analysis is typically a closed-door activity, the PD should be invited to help focus the discussion. This is especially important in the early years of an ERC. Depending on the circumstances, the PD might be invited to say a few remarks at the beginning and then leave, or to remain as an observer or facilitator.

5.6.4 NSF as Evangelist and Shepherd

The Engineering Research Centers Program is a new paradigm for academia, with two new strategies. One strategy is to create a large, multidisciplinary, coordinated research center, where professors from numerous fields collaborate to address complex problems from a systems perspective, under the leadership of a Center Director. This strategy is substantially different from the traditional academic model, in which professors work independently on isolated issues and collaborate only on an ad-hoc basis. The second strategy is to operate as an ongoing partnership with industry, ultimately to attain a state of financial self-sufficiency (that is, independence from core ERC funding). This strategy also differs from the traditional model, in which only a small fraction of professors collaborate with industry on an individual basis—not as part of financially self-sufficient centers—and often only for defined periods and projects, not on an ongoing basis.

The ERC paradigm, with its two new strategies, is innovative and has already provided many benefits to the nation. Still, since the ERC Program challenges the traditional academic culture and traditional views of university-industry collaboration, some faculty in the departments and even in the center may be resistant to aspects of the program. Such resistance can be burdensome—or nearly devastating—to a Center Director. Even among those not directly resistant, time is required to change their outlooks and get them to subscribe to the ERC concept.

NSF serves a vital role as evangelist and shepherd of the ERC concept for both the faculty and industrial participants. The Foundation helps sell the ERC model not only at the beginning of the center, but on a continuing basis, as new participants are added. It helps guide participants away from old ideas and paradigms, toward the current best practices of a strong ERC. Critical assessment of the center's progress is crucial to this role, as is the firm but gentle use of the shepherd's staff.

5.6.5 University-Industry Partnership Strategy: Levels of Interaction

As mentioned previously, one goal of the ERC Program is to create research centers that operated as partnerships with industry. This has required a substantial increase in the extent of interaction between universities and industry.

Figure 5-1 illustrates the kinds of university-industry interaction that are possible, grouped in three distinct levels. At the bottom of the figure is shown the first and most common: the low level of interaction that is traditional between universities and companies.

Second is an intermediate level of interaction, in which information flows not only from the university to industry, but also vice versa. At this intermediate level, the university and industry are helpful to each other as independent collaborators, but neither is highly dependent on the other on a continuing basis. This level of interaction is typical of most successful university-industry collaborations—even most of the famous ones, with substantial economic impacts.

At the top of Figure 5-1 is shown the high level of interaction at which ERCs aim, in which the university and industry are dependent partners.   This level of interaction is rare and, even when created, seldom maintained for long.

The lowest level of interaction is the simplest, but is no longer considered a viable model for the future. The intermediate level requires a high degree of competence, dedication, open-mindedness, honesty, and even altruism among the participants, but no large changes in culture or outlook. With some effort, it can be reached in a relatively straightforward fashion and thereafter successfully maintained. The highest level of interaction requires substantial changes in the culture of both the university and its industry partners. The companies involved must view the ERC as an entirely new type of entity, presenting a new opportunity for the future.   They must view an ERC not simply as part of an educational institution, nor simply as a contract research firm housed within university walls, but as something entirely new.

To be successful and ultimately attain financial self-sufficiency, an ERC must work continuously to draw industrial firms into the highest level of interaction and then successfully interact and derive support from them at that level. NSF serves a key role in helping ERCs reach this difficult but necessary state of being. NSF enforces regular and thorough reviews of every center's progress in university-industry interactions. Shortfalls in progression are identified and addressed in a timely manner, with high priority. Proven techniques to address shortfalls are communicated among staff at different ERCs, through programs coordinated by the NSF. The application of best-practice principles to any particular case is aided by the experience of the Program Director and other NSF staff.

Figure 5-1. Levels of University-Industry Interaction

High-Level Interaction: Dependent Partners

- Formal industrial input regarding systems-level, enabling-technology, and fundamental knowledge needs
- Generic and fundamental research, inspired, sponsored, and monitored by industrial consortium
- Ongoing targeted research sponsored by an individual firm, integrated with their entire research program
- Ongoing technology transfer and licensing, with industrial input throughout process.
- Planned spin-off companies, with industrial input on technology development
- Substantial industrial interaction with students in advance of graduation from the ERC
- Training program scaled to meet current and long-term hiring needs of industrial partners

Intermediate-Level Interaction: Independent Collaborators

- Occasional information transfer among faculty and industrial advisory board members
- Transfer of technology already developed independently at university
- Scholarship funding and other charitable contributions

Low-Level Interaction: Acquaintances

- One-way information transfer: University to Industry
- Short-term recruiting to fill current hiring needs of industrial firm

5.7 OVERALL SUMMARY

The perspective of the ERC's Industrial Liaison Officer is a bipolar one, which involves championing industry's views to academics as well as representing the university center to industry. Most ILOs find common ground in these seemingly divergent points of view, working to promote mutually beneficial interactions between partners from the two cultures. Achieving this balance requires personal and programmatic flexibility as well as diplomacy. Programs developed by effective ILOs often challenge the status quo in both the university and industry. The desire to facilitate their success and learn from their failures is the basis for the suggestions that follow.

The most important lessons learned regarding industrial collaboration are:

- Keep at it—industrial collaboration is difficult and requires continuous effort.
- Inform new members early that satisfaction and benefits accrue to those firms that interact frequently with the center—participating in collaborative research, attending meetings regularly, making contacts, supporting students, seeking information, and giving advice.
- Trust, not a contract, is the basis of a long-term relationship.

Industry wants a solid return on its investment—demonstrable, personalized value for each member company. Therefore:

- For many companies, access to valuable ideas or processes is a significant motive for joining. ERCs must provide members meaningful access to technology on an equitable basis.
- For technology that is not appropriate for protection as intellectual property, members should be given the utmost possible chance to incorporate it in their operations.
- Industry must have a strong role in setting the center's research agenda.

In recruiting members, especially for a start-up center, there are a number of "rules of thumb":

- Tailor recruitment strategies to each prospect; partnership is achievable only if there is a true confluence of interests.
- Maintain frequent and direct personal communications and visits.
- Clearly state the purpose of the center and the role of the company in the proposed center's research and education programs. Share the plans for any characterization or instrumentation facility to be developed. Clearly state the intellectual property rights issues and proposed or developed solutions. Share the university's plans for long-term viability of the center.
- Convince the companies that leveraging resources through center membership provides a strong return on investment, and that the more they participate the more they will gain.
- Discuss with prospective members the uses to which industry funds are put. Also note whether overhead charges on industry contributions will be waived.
- Discuss the commitment of the university and college administration to the long-term viability of the center.

- Create opportunities for industry professionals to interact with students and faculty in such a way that they can influence center programs.
- Discuss center plans for distance learning and short courses.
- Be honest about what you think the center can do for a company, and deliver what you promise.
- Follow-up with required information.

The favorite practices developed by ERCs to facilitate industrial collaboration are:
- Canvassing the Industrial Advisory Board for ideas on directions in research and education
- Cooperative research projects and personnel exchanges
- Student internships in industry
- Technology transfer short courses
- Using senior-level students as links to industry
- Workshops, workshops, workshops!
- Keeping a current contacts tracking database
- Developing solid metrics for assessing the industrial interaction and collecting the data.

NSF—and in particular the Program Director—serves a vital role in helping ERCs achieving the support of both industry and universities. Simply by providing its imprimatur, the agency opens doors for the Industrial Liaison Officers, and builds support for the ERC concept of industrial-academic partnership.

Each center is unique. What works in one may not work in another. If you find that you need more information, we encourage you to call the ILOs at one or more ERCs—especially those participating in the Industrial Liaison Consultancy. We value corporate efficiency for the ERCs and see no reason for anyone to re-invent wheels or not benefit from the collective knowledge of the ERCs' Industrial Liaison Officers and ERC industrial programs.

ATTACHMENT A

NSF Policy Statement on Industrial Membership

1. NSF requires the ERC to develop a Center-level, generic membership agreement that governs industrial/practitioner (hereinafter referred to as industrial) participation and delineates the forms of industrial cash and in-kind contributions that constitute membership in the Center. Industrial/practitioner organizations that can be considered as members include firms, local government agencies, and other Federal agencies. Organizations contributing research and educational participants in the center, such as other universities, institutes, and hospitals should not be included as members. Foreign firms may be members of the ERC as long as they participate according to the membership agreement as U.S. firms do. These industrial members are expected to become involved with the planning, research, education, and technology transfer activities of the Center. Membership fees are pooled and allocated to Center functions according to the strategic and operational plans of the Center as designed and implemented by the Center's leadership. Industrial members may provide additional support above the membership fees for activities such as sponsored research projects, equipment donations, intellectual property donations, or educational grants. Potential industrial members that have not joined the Center, but contribute support for projects that fall within the scope of the ERC's strategic plan and are included in the Center's annual report, are not considered members but may be given another designation, such as affiliates. Attendance or participation at meetings, workshops, seminars, or site visits are benefits/responsibilities of membership, but do not qualify a firm for membership.

2. The ERC shall continue to develop and refine its technology transfer strategy and its intellectual property agreement, the latter in accordance with NSF's intellectual property guidelines (Grant Policy Manual, Section 730, "Intellectual Property") and the Awardee’s policies.

3. The ERC's membership agreement, intellectual property policy must be included in the Center’s Annual Report. A certification of the members and their financial contributions, signed by the university's AOR, must be included in the Center's Annual Report as well.

4. Industrial membership funds must be allocated for Center purposes. However, it is conceivable that they might not be expended in the year in which they are received. If this is the case, these funds must be placed in a Center account and reported to NSF and industry as unexpended funds that are held in reserve for future use. Progress reports on the expenditure of these funds should be provided to NSF and industry.

5. The ERC is required to hold a meeting, no later than three months after the effective date of the first year's award, with its industrial members who have committed to or are interested in supporting the Center. One purpose of the meeting is to gain industrial end-user insights, guidance, and support to help assure that the activities of the ERC are

relevant to industrial interests and needs and enhance technology transfer. Another purpose is to gain industrial input into the development of the Center's membership agreement and the refinement of its intellectual property policy.

6. The ERC is expected to form an industrial advisory board comprised of all member companies and hold meetings of this board at least twice during every year of operation. Each year at one of these meetings, the industrial members will carry out an analysis of the Strengths, Weaknesses, Opportunities, and Threats to survival (SWOT) of the ERC and present the results to the ERC's leadership team. Personnel from selected member companies are expected to participate in the annual NSF site visit where the SWOT analysis will also be presented. The ERC may also develop technical or educational advisory boards.

7. Costs for organizing meetings with industry will be borne by the ERC or the participants through a registration fee, as appropriate. Costs for attending these meetings by industry will be borne by their organizations.