Chapter 5: Industrial Collaboration and Innovation

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5.0 Overview

This chapter discusses some of the most effective practices that existing ERCs have learned to use in conducting industrial collaboration and innovation programs. It addresses issues such as establishing a partnership with industry, building an industrial constituency, the benefits and difficulties of industrial interaction, building an "innovation ecosystem," and the role that the NSF plays. Case studies are used to illustrate some effective approaches. Abbreviations for ERCs that are referenced in these case studies are defined in Attachment 5-A. This chapter also defines the innovation ecosystem, along with the management and delivery of intellectual property from the perspective of ERC planners. It ends with a discussion of the role of the ILO within the ERC.

A central motive of the National Science Foundation (NSF) Engineering Research Centers (ERC) program is to form partnerships between academia, industry, and innovation-focused entities in systems-oriented research areas that are critical to the Nation's future economic strength. Each ERC collaborates with industry and other practitioner organizations from the early inception of its vision creation and subsequent strategic planning, and this collaboration extends to technology development and application. By thus expanding and accelerating technology translation, transfer, and eventual commercial use, this approach bridges the traditional innovation gap between the single university investigator and industrial adopters of academic research results. ERCs develop a group of members that includes firms of all sizes along the value chain of sectors important to the realization of the ERC's engineered systems vision.

By embracing industry and innovation throughout the entire cycle of technology creation, development, and implementation, the ERCs are distinctive among NSF research centers. Each second-generation (Gen-2, Class of 1994-2006) and Gen-3 (Class of 2008 and beyond) ERC is tasked to develop a membership program for industrial collaboration and technology transfer. In addition, each Gen-3 ERC is challenged to expand that program to include state and local government or university organizations devoted to stimulating entrepreneurship and innovation—the innovation facilitators. Both Gen-2 and Gen-3 ERCs are expected to stimulate technology transfer through member firms by means of information exchange, hiring of ERC graduates, member-funded sponsored research projects, and translational research with small firms when member firms fail to license new ERC-generated Intellectual Property (IP). Both Gen-2 and Gen-3 ERCs are charged with developing graduates who are better prepared for effective practice in industry and leadership in technological development. In addition, Gen-3 ERCs are charged with developing graduates who are more creative and innovative and better prepared for leading innovation in a global economy than their non-ERC counterparts are.

Thus, each ERC team envisions and plans transformational technology and education with its industrial/practitioner[1] partners from the outset. Each center's strategic plan, developed with industrial partners, 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 are required to 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.

In 2012, ERCs reported corporate memberships ranging from 7 to 47 companies per center (averaging 23 per center). 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, small firms (<500 employees) and large firms (>1,000 employees) make up 43% and 48% of the members, respectively.

For established centers, industrial/practitioner member organizations provided 9.4% of the total ERC direct support in 2012 (5.4% unrestricted cash, 1% sponsored projects, and 3% in-kind contributions). Including support provided by organizations who were not members, this percentage rose to 11.7% of ERC direct support for 2012.

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 2012, a total of 676 patents had been awarded to 61 ERCs between 1985 and 2012; 1281 licenses had been issued to companies; and 146 companies had been formed as spin-offs of ERC research, with a total of 1,032 employees. In addition, hundreds of discrete innovations had made their way into use in industry. The ERC Program invested over $1.0B in ERCs between 1985 and 2010, with a return on investment in the 10s of billions of dollars[2].

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 centers (years 1-3) necessarily focus on strategic planning with industrial partners, 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, and beginning to prepare for self-sufficiency. Mature centers (years 8-10) 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 initiate long-term sustainability planning jointly with their industrial partners well before the end of ERC Program funding, ideally as early as year 4, with significant progress by year 6.

Experience shows that the enthusiasm and appeal of a start-up center is very effective in attracting industry involvement; but as centers mature and sponsors become more demanding, industrial collaboration requires more work. On the other hand, age confers the advantages of experience and credibility. In the early stages, centers sometimes 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, in preparation for self-sufficiency, centers may begin to add sponsored projects funded by specific industry partners, where the research on these projects would include a focus on applications and firm-specific development based on the ERC knowledge generation and technology developments. Care should be taken to maintain a strong base level of support that enables discretionary funding of core projects and new and exploratory work. The ERC should be mindful not to turn the center into a "job shop" for industry or a collection of applied and often closely held sponsored projects as the time for self-sufficiency from NSF support comes into play.

The center's life cycle in the first few years is somewhat analogous to NSF being a venture capitalist, funding a build-up of infrastructure and providing substantial leverage to industrial support. But the venture capital analogy projects the wrong relationship between NSF and the ERCs because NSF is not looking for a direct monetary Return on Investment (ROI); rather NSF's expectation is that the Foundation's return on investment is in terms of high-quality research, impact on national economic development, etc. 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.

But industrial collaboration with ERCs extends beyond the development and transfer of technology. Industrial members are stakeholders in more than just strategic planning and collaborative research. They also have a vested interest in the ERC's educational activities because of the impact on their workforce development. 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. The university and/or state and local government innovation partners in Gen-3 ERCs become more involved in stimulating entrepreneurship and promoting innovation.

Industrial involvement in the early stages of technology planning and development provides substantial payoffs when ERC students graduate. 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 "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 5.2.4.1 for a more detailed discussion of the job performance of ERC graduates.)

The ERCs' relationships with companies and practitioner organizations are situation-specific to some degree. Each one is unique, depending on the nature of the research undertaking, the scope and type of the industries involved, the strategic direction of the center, and the personalities of the leadership team. 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 constituency of industry and government practitioner stakeholders. 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 truer of the centers that have graduated from NSF support, since those centers operate without the NSF ERC award and therefore must justify their benefits to both their host universities and their industrial members.

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[1] Practitioner partners are organizations that will support the ERC's research as center members and will use the outcomes in the delivery of services; these include local government agencies, hospitals, etc. Industrial/practitioner partners will be referred to as industrial partners or industry members throughout the rest of this document.

[2] Engineering Research Centers: Innovations—ERC Generated Commercialized Products, Processes, and Startups, Courtland S. Lewis, February 2010. (http://www.erc-assoc.org/topics/policies_studies/ERC%20Innovations%202010-final.pdf)

5.1 Establishing an Industrial Affiliates Program

A critical initiation activity in any center is establishing buy-in for the vision and putting in place the infrastructure that is required for effective industrial collaboration and innovation programs, including agreements with stakeholders, marketing programs, and systems for tracking interactions with industry and innovation partners. The Center Director and senior leadership of the center typically form the vision and strategic plan for industrial interaction and innovation during the center's proposal development process. The infrastructure required to affect this vision and strategic plan must be developed and honed with post-NSF self-sufficiency in mind.

In the initial months of new ERC formation, 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, as discussed in Section 5.1.2. It is important to remember that this must be an ERC-wide agreement that includes an ERC-wide IP policy, encompassing the lead and partner institutions.

In 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 awarding of the cooperative agreement, and the climate for negotiating long-term university support is strong. Be mindful that some universities may have Industry/University Cooperative Research Centers, where the agreements are different from ERC agreements and some university officials may not be aware that they are different.

Experience shows that while many ERCs may have one or two technical disciplines and therefore departments that dominate the ERC researcher and student populations, ERCs are by their nature cross-disciplinary and therefore will involve talent and infrastructure from multiple departments, and sometimes multiple colleges—although Colleges of Engineering should and do dominate, as one would expect. ERC Directors must report to the Dean of Engineering.

5.1.1 Foundational Agreements to Establish Industry Collaboration and Innovation

Establishment of an ERC requires certain foundational agreements to be expeditiously put in place in order to set the stage for success. It is critical that the ERC and host university complete these agreements as early as possible in the ERC's first 12 months in order to establish a sound working protocol with all ERC stakeholders.

5.1.1.1 ERC Agreement with Host University Regarding Overhead and IP Returns

One key element of structure is the development of an agreement in the early initiation of the ERC regarding overhead and technology licensing returns to the ERC cost center vs. other university cost centers such as the disciplinary departments. Clearly, overhead return discussions can become problematic if faculty are conflicted between submitting proposals (industry or federal agency funded) through their home department vs. the ERC.

Similarly, many university intellectual property policies provide technology licensing royalty, fee, and equity liquidation returns to various units (university research office, college, department, inventors) and sometimes include "centers" or "research units" if the invention was spawned in a separate unit. ERCs should get specific, early commitments on what overhead and royalty returns will flow to the center to avoid confusion and hard feelings downstream. If the center is not included initially in IP licensing returns, the director can approach the university administration 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 participate in royalty and equity liquidation returns and set those policies in place early.

All centers work with their university intellectual property officers to comply with university standards on such matters. A good working relationship with the university IP administrators is important in developing a successful partnership with companies. Since centers span more than one university, clear agreement among the administrations of all the academic partners is essential. Procedures for notifying industrial partners of the existence of center-developed IP should be clarified between the center and the universities' intellectual property officers. In all cases, IP agreements should accord with regular NSF guidelines, as set forth in the effective NSF Grant Policy Manual.

5.1.1.2 ERC Host University Agreement with Domestic Partnering Universities

The ERC host university should work diligently in the initial year of the ERC to assure that agreements with partnering universities involving intellectual property management rights and responsibilities, reporting responsibilities, industrial partner benefits, etc., are consummated at the start of the Center's life. Of specific concern is to assure that the research review and intellectual property rights provided to industrial partners of the ERC through their industrial membership agreements accrue to them regardless of which partnering university faculty are inventors. This should include clear and unambiguous agreement as to industrial partner benefits from core research funded by membership fees, the ERC award, university cost sharing, and other funds provided to the ERC without restriction regarding use, as opposed to sponsored project research supported by industry or other sources. Industry membership agreements typically provide rights to core research of the ERC, with no mention as to the origin of inventions from that core research. Rights granted to industry partners must be consistent with inter-university agreements and ERCs must assure that this is codified in Inter-institutional Agreements or subcontracts at the time of engaging initial industry partners.

CASE STUDY: The issue of "royalty distribution" back to the ERC instead of the home department of the inventing investigator(s), for inventions arising from ERC research, is a sensitive one. University policies vary greatly, and the question of what is fair is valid. One example is the long-graduated Data Storage Systems Center (DSSC), at Carnegie Mellon University (CMU), which was an ERC from 1990 to 2001. This now self-supporting center produced some key technologies in data recording that continue to have an impact on the industry today. CMU's Intellectual Property policy is one of the most liberal in the country, in that it gives 50% of all royalties to the inventor(s) and 25% to the research unit (in this case, the DSSC), retaining only 25% for the university, which actually owns the patents. Most universities retain considerably more. One factor in CMU's decision to allocate the research unit's proportion of the royalties to the DSSC is that DSSC holds a considerable portfolio of patents, and the Center pays the cost of each of those patent applications. Royalty returns to both the Center and to individual faculty and even students have, at times, been substantial and have contributed significantly to the DSSC's success in maintaining self-sufficiency. Based on this history and that of other ERCs, the NSF ERC Program management believes that ERCs should negotiate with the host and partner universities a portion of licensing returns to the ERC (royalty, equity liquidation, and other forms of payment such as fees and litigation returns) for ERC-generated technology, as a unit of the university's research enterprise. The rationale for this is that it is the cross-disciplinary research program and the ERC's testbed culture that have generated the technology, not the investigator's laboratory alone. It is true that university administrations will likely be resistant to changing their royalty return policies; negotiations after the award is made might actually be easier than at the proposal stage. Although NSF recognizes that the high levels of return that DSSC enjoys are extremely rare (even anomalous), there are several other centers with this type of royalty distribution allocation, although at lower percentages. DSSC provides an example of the impact that this issue can have on ERC self-sufficiency.

5.1.1.3 ERC Agreement with Foreign University Partners

One area that merits further discussion is the formulation and execution of international agreements with foreign university partners. This originally was a required component of a Gen-3 ERC, but because of the complexities outlined below, beginning in FY 2013 a Gen-3 ERC may enter into a focused partnership with a foreign university governed by a formal agreement with mutually protective IP policies, or faculty-to faculty collaborations. In either case, the partnership/collaboration must allow for ERC students to spend at least 30 days working in the laboratory of the foreign partner/collaborator.

The establishment of the ERC/foreign university partnership agreement can involve a steep learning curve, concentrated on the complexities of international law and the vast differences in scientific culture and legal environments, especially in intellectual property ownership and business law specific to the partnering university's home nation. The "harmonization" of the final international agreement can take a great deal of time and expense that an ERC has to bear. These agreements need to engage the highest levels of the administration on both sides (university presidents, university system officials) from a policy and legal standpoint. The following is a case history of the IP issues involved in an exemplar ERC/foreign university partnership.

CASE STUDY: A partnership was formed between the Revolutionizing Metallic Biomaterials ERC (RMB) based at North Carolina Agricultural and Technical State University and the University of Hannover Medical School in Hannover Germany. North Carolina A&T, as the host university on behalf of the ERC, negotiated a fixed fee with a local law firm with international business and IP law expertise to interpret German law and to draft a harmonized agreement. The German Inventors law differs from the Bayh-Dole Act in that, rather than assigning intellectual property rights to the University, German scientists and engineers retain rights to their inventions. German Law allows for a period of time in which a German employer (University) may secure rights to an invention in return for fair compensation to the inventor at the time of transfer of rights. If this option is not exercised in a timely manner, IP rights remain with the inventor. This arrangement tends to limit the nature of the global interaction between Hanover and the ERC to student and technical exchanges, as the ERC cannot ensure that IP obligations under Bayh-Dole will be met in cases of joint inventorship between an ERC investigator and a German investigator. It may be possible to address this concern. Opportunities for the ERC to participate in the option discussions between the University and the German inventor are being explored.

As exchanges occur and joint IP becomes an issue, the agreement needs to include some mechanism to capture that IP under mutually protective terms. Additionally, ITAR and export control restrictions, especially with the development of new materials, need to be addressed in terms of international agreements. This could impact the exchange of information, materials, samples, and prototypes.

Faculty-to-faculty collaborations would operate under less formal terms, as is traditional in academic research. However, the ERC still needs to be mindful to protect ERC-funded IP.

5.1.1.4 ERC Agreement with ERC Researchers

One area that is easy to overlook is clarifying and codifying the relationship between the ERC and its researchers at the different partner universities. While this may seem trivial, as university faculty and students are typically accustomed to working in various research groups and with myriad affiliations, the ERC is different in that it has specific requirements of its researchers and also provides specific benefits (e.g., intellectual property rights) to industry partners. The ERC has an opportunity early in its existence to establish a clear understanding with researchers funded by the ERC as to what is expected of them and what they can expect of the ERC. While this agreement can be as complex as the ERC desires, simplicity usually serves all parties better. The agreement may be as simple as a letter of understanding between the ERC and relevant researchers outlining what is expected of them (e.g., participation in industry meetings, collaborating with industry partners on a reasonable and mutually beneficial basis, contributing to ERC reports to NSF or industry partners). Additionally, this communication should also inform the researchers of industry partner intellectual property rights granted through the ERC Industry Membership Agreement. Most universities outline researcher rights and returns from IP through a university intellectual property policy, and the ERC agreement may provide for rights that impact researcher returns from their technology (e.g., their return of IP royalties may be impacted if the ERC provides partners with a non-exclusive royalty-free right to use of inventions from ERC researchers).

5.1.1.5 ERC Agreement with Student Researchers

After knowledge generation, one of the most important outputs of the ERC is the students it graduates. But the ERC graduates and post docs are more than just statistical outcomes of NSF's investment. They are also stakeholders in the ERC enterprise and as such they have a voice (through the student leadership council) and rights that need to be protected. Given the Gen-3 ERC's drive to facilitate the translation of technology to the commercial sector, situations where an ERC participant has significant financial interests in the collaborating firm or other entities affected by the proposed research are beginning to emerge. These constitute conflicts of interest (COI) that must be managed by the participant's home university. An important aspect of managing the conflicts is for the home university to put in place policies that protect students, should their dissertation work potentially affect the value of a company in which the faculty advisor has an ownership or managerial interest.

CASE STUDY: Virginia Tech has various policies and procedures on managing conflicts of interest for the protection of students. For example, an informational page on protection of students and trainees in projects sponsored by faculty-owned businesses (Policy 13010, which can be found at http://www.policies.vt.edu/13010.pdf) contains the statement "This policy provides the basic framework for assessing potential conflicts of interest or commitment and outlines related procedures for the management and monitoring of external activities in a manner that will both promote and safeguard the interests and reputation of Virginia Tech, its faculty and students, and their research." Another example is Protecting the Interests of Students and Trainees (which can be found at https://www.research.vt.edu/conflict-of-interest/students-and-trainees). This document begins with the statement "The impact of a perceived or actual conflict of interest or commitment of faculty members on their students (including post-doctoral fellows and other trainees) is of special concern to the university. In particular, the university is committed to maintaining the content and quality of the educational experience for students whose research is sponsored by a for-profit business and whose faculty advisors have a financial interest or a management role in that business. The concern is even greater if the dissertation work could potentially affect the value of a company in which the faculty member has an ownership or managerial interest."

5.1.1.6 ERC Agreement with Industry Members

Along the same lines, ERCs under the direction of the ERC Director, ILO, and university technology transfer and contract offices should put significant effort into finalizing industrial partner agreements very early in the life of the ERC, ideally within the first few months of award. This is critical as ERCs typically start with a cadre of industry partners that have participated in the pre-award activities and this base can grow quickly with proper recruitment. Changing an industrial partner agreement becomes much more difficult, and dangerous in terms of losing current industry partners, the further downstream agreements are put in place or modified. This topic is covered in detail in

Section 5.1.2.

5.1.2 Establishing the Membership Agreement

Within the first few months after the start of the ERC's award from NSF, 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. It is critical that establishment of this membership agreement be completed as early as possible in the life of the ERC—certainly within the first year of NSF contract award—since establishing an agreement that is acceptable to the ERC, partnering universities, industrial partners, and innovation partners early will capture the partners' excitement as the ERC is established, resulting in establishment of the initial industrial partner consortium. In addition, if the ERC Program first year site visit team finds no firms or only a few that have signed on to be members of the center because the agreement took too long to finalize, that will not bode well for their judgments regarding management of the ERC.

An ERC should not to try to develop individual contractual arrangements for each company in lieu of a membership-defined program of industrial collaboration that encompasses all members. It's critical that the membership agreement be well established, as there will be little to no room for modification once the industrial membership base is built. Any downstream modifications to the membership agreement that potentially impact current member rights would then need to be renegotiated with all affected members—typically not a viable situation and one to be avoided at almost any cost.

Organizations that can be considered as ERC members include private firms as well as local and Federal government agencies that have joined as members, agreeing to financially support the ERC through the payment of fees and participation in its research and education programs, per NSF ERC policy. Organizations contributing staff to carry out research and educational projects in the center, such as other universities, government agencies or laboratories, institutes, and hospitals, should not be counted as members. In addition to paying fees in cash, member companies/practitioner organizations may augment their support to the center through in-kind contributions as part of the membership fee or in addition to the fee structure. Finally, additional support for directed sponsored projects or contractual arrangements is a way to speed the translation of ERC-developed technology into use.

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." Additionally, entities that contribute primarily to the innovation mission of the ERC are considered Innovation Partners, as discussed in Section 5.3.3.

Guidelines for ERC industrial membership agreements, including example agreements, are available to registered users of the ERC Association website at www.erc-assoc.org/ilo-forum.

The overall intent of the Industrial Membership Agreement is to establish a contractual relationship that is:

1. mutually beneficial and equitable to both parties of the agreement;
2. scalable to a large ERC industrial membership;
3. applicable to companies of all sizes (small and large); and
4. clearly outlines the rights and obligations, if any, of company subsidiaries, sister, or parent organizations.

5.1.2.1 Necessary Elements of the Industrial Membership Agreement

In establishing an industrial membership agreement, the ERC must balance the need to keep the agreement as simple and straightforward as possible so as to make a single agreement palatable to the many companies the ERC will engage as industry partners vs. the need to assure that the document equitably addresses all of the critical elements of such an agreement to avoid downstream lack of clarity on terms and conditions (e.g., IP management and publication rights). In order to assist in this important activity, NSF has established a Gen-3 Membership Agreement Checklist to guide new ERCs in necessary elements of a membership agreement. The NSF Gen-3 Membership Agreement Checklist requires that ERCs consider the following in establishing industrial membership agreements[1]. Specifically, does the agreement:

1. Function as an ERC-wide membership agreement, encompassing the lead and core partner universities
2. Define which institutions are considered lead and core partner universities in the ERC and their responsibilities to the ERC
3. Define the types of organization that are allowed to join the Industrial Advisory Board (IAB) and specify the following IAB responsibilities to the ERC:
    1. meets a minimum of twice a year;
    2. develops an annual Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis;
    3. participates in NSF annual reviews of ERC performance and plans and present the IAB SWOT; and
    4. provides input on strategic research and education plan, ongoing project performance, and proposed project plans.

1. Define:
    1. IAB Membership categories;
    2. IAB Membership fee structure (perhaps include a table using the format of Table 5.1 below to tabulate membership fees for each member category);
    3. what it takes to maintain membership in good standing;
    4. benefits received for each level of membership;
    5. terms of membership and termination;
    6. conditions for acceptance of “in-kind” in addition to cash. (This is permitted at the Center Director’s discretion, but it must be at a discount rate of 30% to 50% of retail value. Furthermore, the aggregate amount of dues collected as discounted in-kind payments should not exceed 25% of the cash dues collected);
    7. core research and the sources of funding for the core research; and
    8. non-core research and the sources of funding for associated and sponsored projects;

Table 5.1: Sample IAB Membership Structure Matrix

Rights and Benefits	Member Category #1	Member Category #2	Member Category #N
Right #1			
Right #2			
Benefit #n			

1. Define how information that is considered to be confidential will be handled among the ERC and IAB parties
2. Define how publications with potential IP implications will be handled, vis-a-vis protecting the IP rights of IAB members
3. Define the following with respect to IP:
    1. require that joint IP agreements be in place across all universities;
    2. require that joint IP agreements be in place between ERC and industry researchers;
    3. when and how one determines that research developments are to be classified as intellectual property and who owns the IP;
    4. when must a firm be a member in good standing in order to qualify for the first option to license the technology;
    5. maximum time period that the members of the IAB are granted to review and claim the first option to license ERC-generated technology (if this is too short it can appear to industry that the faculty want to reserve technology for their own spin-out firms, or if it is too long it can retard the advancement of new technology);
    6. whether non-exclusive royalty free (NERF) licenses are granted for research only;
    7. whether exclusive licenses take precedence over NERFs;
    8. the conditions under which exclusive royalty bearing licenses are granted;

9. IP terms for sponsored projects; and
10. a process for qualifying to apply for translational research funding from NSF that is consistent with the flow diagram in Figure 5-6 of Section 5.3.2.1 and the Program Terms and Conditions (PTC) outlined in Section 4.e.iv of the ERC Cooperative Agreement (See Attachment 5-B).

5.1.2.2 Structure of the Industrial Membership Agreement

Attachment 5-C provides a sample membership agreement that can be used to inform new ERCs of the critical elements of an ERC Industrial Membership Agreement and sample language that has been successful in such ERC agreements over the years. It should be noted that this sample agreement is not meant to be prescriptive, but instead to act as a guide to ERCs as they establish their Industrial Membership Agreement specific to their university and industry needs.

The following is offered as general guidance as related to the elements of the Sample ERC Agreement provided in Attachment 5-C:

- General Obligations of the ERC Host University, Partnering Universities, and Industry Members—The university and industry partners must manage expectations and clarify what each entity can expect from their partners and, as importantly, what is not included as part of the partnership. This is especially critical early in the life of the ERC, as industry champions are engaged but provide a minority of the overall ERC funding.
- Relationship of the University Partners and Industry Members' Rights—This element is important in defining the extent to which the rights and obligations of the industry members extend across the ERC's university partners. It is standard practice that industry members enjoy consistent rights provided through their ERC Industrial Member Agreement (e.g., Intellectual Property) across all partnering universities; but this is an issue for the university partners to address, codify in Inter-institutional Agreements (IIAs), and clearly transmit to industry members.
- Expectations and Obligations of Industry Members—Industry members must understand that they are expected to play a critical intellectual role in the ERC in addition to financially supporting the center. Specifically, industry members are expected to support the research, education, diversity, technology transfer, and innovation goals of the ERC, including: demonstrating the scientific and technological feasibility of innovative methodologies and systems; assisting in the transfer of research discoveries and observations from the university to industry and vice versa; and developing an interdisciplinary education program that prepares diverse cadres of domestic ERC graduates for effective industrial practice with U.S. firms and provides opportunity for enhancing creativity and innovation. At a minimum, the industry members should commit to: meeting at least twice a year; developing an annual SWOT analysis; participating in NSF annual reviews of ERC performance and plans; and providing input on the ERC's strategic plan, ongoing project performance, and proposed project plans. Some ERCs have chosen to codify these requirements in the Industry Member Agreement while others have chosen to include them in ERC Bylaws that are then included by reference in the Industry Membership Agreement. Either is acceptable, but what is expected of industry members should be clearly explained in a broadly applicable document. This approach allows more flexibility in defining the role of the IAB without having to renegotiate the agreement with each firm.
- Entities that are Eligible to Serve as Industry Members—Various business entities and government agencies may become industry members. Some ERCs have chosen to include investment groups (e.g., venture capital entities) that technically meet this definition; but the ERC must be cognizant of the challenges and opportunities presented, and may instead choose to include these groups as innovation partners or other partners. The details and implications are discussed in Section 5.3.3.
- Use of Resources—It's important to clarify the flexibility and bounds that the ERC has in allocation of resources, including industry member fees, so as to establish a support base for the entire scope of the ERC program (e.g.. research, education, outreach, technology commercialization, and innovation), as opposed to the restricted scope encompassed by a sponsored project..
- Term and Termination—Different ERC's choose to provide an initial term for the Industry Member Agreement of one to five years to suit the needs of the types of firms in the ERC's value chain. Obviously longer terms, with appropriate termination conditions as discussed here, are beneficial for planning purposes, but may not be palatable to all industry members, so some flexibility may be required. The Sample Agreement provided in Attachment 5-C provides for an automatic renewal (aka an "Evergreen Clause") for an annual term. This clause is desirable for the ERC to include regardless of the term of the

agreement, as the agreement will then roll over to subsequent terms without further management or legal review triggered—simplifying renewal for both the university and the industry member. A mutually acceptable termination clause through written notice is considered standard so long as the notice period is sufficient to not disrupt research and education programs and student progress.

- Applicable Law—Most public universities must operate under the laws of their state and little flexibility may be available here, other than for the agreement to remain silent on this issue if acceptable to the university and the industry member.
- Publication Rights—Industry members must understand that publication of ERC created research results is of fundamental importance to universities, faculty, and students. At the same time, industry members should expect that they have the opportunity to harvest commercial value from ERC scientific advances as outlined in their Industry Membership Agreement. As such, clarity on the process, conditions, and timing of publications with regard to IP protection and review of data is essential in the agreement. The university and industry must be comfortable with these terms and the process that will be followed. One such version is outlined in the Sample Agreement of Attachment 5-C.
- Confidentiality—This clause captures the intent of both parties to maintain the confidentiality of information marked as such that may be passed between the parties. This can be through individual project collaborations as well as during Industrial Advisory Board meetings. The ERC should consider specific Confidentiality Agreements for such information transfer as appropriate, but this statement is important to include for general information that might be exchanged in order to foster more open communications between the parties. This statement should be reviewed carefully by the university legal counsel.
- Other Rights and Obligations—As outlined in the Sample Agreement, other rights and obligations that are usually non-contentious but important might include equal opportunity and non-discrimination, use of names, the legal relationship between the parties, liability, and representation. These and others that might be required by the universities should all be clarified in the agreement.
- Intellectual Property Rights and Management—IP management is typically the most difficult portion of the agreement on which to agree, and is also one area with the least flexibility once the agreement is executed with the first industry members. There is very little to no room for downstream modification to IP terms as the ERC builds the industry member base, as any downstream modifications would typically affect rights of existing industry members, which would then require renegotiation and execution of the agreement or an addendum capturing the changes. This portion of the agreement is typically the most difficult to craft and, as such, is dealt with in detail in Section 5.3.2.
- Membership Structure, Fees, and Benefits—The membership structure can be simple or relatively complex, with tiers for both membership category and company size, and so is dealt with in detail in Section 5.1.2.3.

5.1.2.3 Membership Tiers and Fees

Across all ERCs, annual industry membership fees have ranged from $1,000 to $250,000, usually encompassing a tiered membership structure that includes two or three membership categories with corresponding fees and benefits of membership. While various benefits as discussed below can accrue to the highest membership tier, lower level members may not enjoy benefits such as favorable access to IP.

Many centers allow larger firms to affiliate either in limited ways (by research area or by specific contractual projects) or in a broader way (full membership with maximal rights), with fees usually ranging from $10,000 to $50,000

Company size can also be a differentiator in fee structure. ERCs often will provide a discount on the membership fee for mid-size or small companies, in some cases even for “start-up companies”, to encourage their full participation and spur technology transfer and innovation.

ERCs typically define mid-size or small companies by either number of employees (less than 1,000 employees for mid-size companies and less than 100 employees for small companies is within reason, but this may go as high as 500 employees for small companies) or sales of products or services that are in the field of the ERC. The cutoff for mid-size or small companies is subjective and at the ERC’s discretion, but should be perceived as fair to larger companies when considering benefits and the ability to contribute to the ERC. For small companies, fees are generally $1,000 to $10,000, and may be graduated. Fees for mid-size companies are generally $10,000 to $25,000, but again this is highly dependent on what is palatable to the ERC’s target industry.

In some cases, the ERC may choose to accept industry members’ fees on a quarterly or semi-annual basis, or alternatively to accept partial payment from multiple groups or departments in order to meet company departmental funding limitations or processes. Additionally, the ERC must balance the convenience of establishing contract and payment terms on the ERC's preferred fiscal cycle (many times this is the university fiscal year) vs. being flexible to industry needs with regard to their fiscal cycles.

Even the definition of the "number of employees" can evoke discussion when recruiting industry members. Larger companies will sometimes argue that their research group focused on the ERC's field is a small portion of the company and so the company should be able to participate at a mid-size or small company fee level. Many times, the company group with which the ERC works is in fact a smaller research or development oriented group, with smaller discretionary budgets. In the same light, companies may wish to share ERC information and technical results with affiliates or subsidiaries of the company. This is a difficult situation for ERCs. One suggestion provided by a number of industry partners is to define the company size by the number of employees that have free-flow access to that group's internal technical information as part of their normal business processes. In that way, the ERC relationship does not create an artificial firewall to the group's regular R&D information flow, since the ERC results flow in the same pathways, and to the same employees, as the group's internal information. At the same time, the ERC is properly compensated for access to its information and results.

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 that contribute support for associated 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 are designated as "affiliates." Some centers use all membership fees to support research; some use them exclusively for support of student interns; others use membership fees for all operations.

5.1.2.4 In-kind Contributions in Lieu of Cash for Membership Fees

Centers' policies vary on how fees are paid—in cash, in-kind, or a combination. ERCs may find that in-kind contributions are valuable in the early stages, when equipment is needed and relationships require nurturing. Additionally, small companies that have unique equipment may not be able to pay a cash fee, but cutting-edge equipment donation can be of greater value to the ERC and other industry members who make use of ERC infrastructure or data from that equipment. If equipment is taken as in-kind, the ERC should strive to include maintenance and upgrade clauses in the agreement so as to protect against a downstream cash drain. For the purposes of membership fee payments, many ERCs value equipment at a 30-50% discount from industry retail value, not academic discount pricing. Additionally, many ERCs will limit overall in-kind contributions to no more than 50% of the overall pool of membership fees to assure a focus on cash membership fees, which provide liquidity and flexibility to meet the ERC's overall program needs. This is even more important as the Center grows and prepares for self-sufficiency beyond the NSF funding cycle. Exceptions can be made for cash-poor small firms.

In 2012, ERCs reported corporate memberships ranging from 7 to 47 companies per center (averaging 23 per center). 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, small firms (<500 employees) and large firms (>1,000 employees) make up 43% and 48% of the members, respectively. In addition, several centers have federal laboratories as members. Some include industrial consortia. In that case, the consortium joins as a member, but the members of the consortium must also join individually in order to reap the benefits of the ERC. Overall, for established centers industrial/practitioner member organizations provided 9.4% of the total ERC direct support in 2012 (5.4% unrestricted cash, 1% sponsored projects, and 3% in-kind contributions). Including support provided by organizations that were not members, this percentage rises to 11.7% of ERC direct support for 2012.

5.1.3 Industrial Membership Rights and Responsibilities

Clearly identifying and promoting what the ERC expects of its industry members and what they can expect of the ERC is key to a strong, long-term, mutually beneficial relationship.

5.1.3.1 Member Rights

While appropriate industrial membership rights are usually industry-specific and should be determined by the ERC's leadership to optimize value to their specific industry members and the ERC, general guidelines from the ERC program can inform new centers on what has successfully provided value to industry partners. Rights of industry members are typically tiered for the level of membership as discussed in Section 5.1.2.3 and may include:

- Rights to serve on the Industrial Advisory Board (IAB) and the opportunity to serve as an elected representative on the Technical Executive Committee (TEC) or equivalent, if one exists. The IAB typically consists of all industry members in good standing and the TEC is elected by members of the IAB to provide the highest level of guidance to the ERC in an effective and efficient manner. The TEC is constituted to ensure the overall synergy of the research carried out in various research thrusts and to recommend to the ERC Director any needed mid-course corrections in research and/or personnel.
- Rights to receive a discounted university overhead rate, applied to any additional research in the field of engagement with the ERC associated with ERC researchers which the members sponsors outside of the Membership Fees. The university may request that this also requires up-front payment of the sponsored research fee to minimize the overhead burden to the university.
- Priority access over non-members to ERC facilities and instrumentation, sometimes at reduced fees.
- The right to request on-location short courses provided by ERC researchers, at reduced fees.
- Access to the ERC's secure website, comprising an electronic information network containing ERC reports, publications, and invention disclosures
- Intellectual property rights as discussed in Section 5.3.2

Whatever benefits are offered, the ERC must assure that these rights extend only to the industry member departments, internal groups, affiliates or subsidiaries that are included in the definition of ERC Industry Members in the agreement (e.g., those that share in the free flow of the member's internal technical information as discussed in Attachment 5-C).

5.1.3.2 Member Responsibilities

In addition to payment of the annual membership fee, industry members of an ERC are expected to undertake appropriate interactions with ERC leadership and researchers to help the ERC accomplish its mission. Members are encouraged to pursue a high level of engagement with the ERC to best guide the center and to take maximum advantage of all the ERC has to offer. Interactions come in many forms including:

- Visits to the member firm/agency by faculty and students
- Discussions at professional society meetings or conferences
- Visits to the ERC as often as practical to work collaboratively on research projects, mentor students, learn specialized techniques, and give special seminars

- Providing advice on developing the ERC strategic plan
- Reviewing overall progress against strategic goals

- Suggesting changes to the strategic plan, research, and education efforts
- Identifying areas for cooperation with industry or, in some cases, other institutions
- Reviewing invention disclosures and suggesting patent and copyright actions
- Critiquing the progress and direction of each research project
- Providing resources the research program may need
- Suggesting industry speakers for workshops and seminars.

While these and other types of interactions should be strongly encouraged with all industrial members, there are certain duties and responsibilities that are required of members and that must be part of the Industrial Membership Agreement:

- Meeting with the ERC a minimum of twice a year

- Developing an annual SWOT analysis and presenting to the NSF site visit team
- Reviewing progress on ERC projects
- Providing input on ERC strategic plans
- Providing feedback on proposed project plans.

5.1.4 Engaging Industrial Consortia, Regulatory Agencies, & Industry Associations

In working with external industrial consortia and with state and local governments—particularly those agencies involved in economic development—the ERC will need to meet specific consortium or agency goals while assuring that such interactions 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 as discussed below.

Some Centers have actively engaged their target industry's relevant regulatory agency or other non-traditional organizations in their programs. For example, the Food and Drug Administration (FDA) is actively engaged C-SOPS Industrial Advisory Board and Science Advisory Board[2]. Also, the engagement of the US Department of Agriculture (USDA) by CBiRC produces a distinctly positive relationship. ERCs should consider having regulatory agencies interact with the academic community and industry partners in ERCs where appropriate. Any regulated industry that is an ERC focus field should consider having regulatory bodies involved in a "neutral setting," to facilitate active interactions between faculty/students, industry, and the regulatory agency.

CASE STUDY: In the case of C-SOPS, faculty taught courses at FDA to provide knowledge of current and future practices in continuous manufacturing. The course was attended by many FDA employees and provided critical thought into science-based regulatory processes. The FDA proposed regulatory guidance, such as Quality by Design (QbD) and Process and Analytical Technologies (PAT) pertaining to continuous manufacturing, and through such courses FDA personnel gained a clearer understanding of detailed continuous manufacturing processes. This reduces the amount of uncertainty for industry. The C-SOPS Director served on FDA committees that draft guidance documents. C-SOPS recognizes the value of doing this independently to develop Best Practices. The limiting factor is not money, but the time of the personnel involved. Through closer alignment of regulatory and industry practices, C-SOPS can ensure that technological advances will be more readily accepted by the FDA and can subsequently be incorporated into industrial practice, providing significant impact to both.

Groups involved with standards development (e.g., ASME, IEEE) could be ERC education and dissemination partners. An ERC needing manufacturing capabilities might gain access to an industry group that could translate and manufacture outputs of the ERC and possibly collectively gain companies that would not join the center, but could add value to Center activities. In cases where the ERC has a significant life science / clinical focus, the ERC might consider engaging a Clinical Advisory Board, which is integral to the Scientific Advisory Board (SAB).

Several centers are participants in other federal programs (e.g., those of DARPA and NIST). 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.

Some ERCs—especially those whose mission focus is in public infrastructure development—partner with federal, regional, state, and even local government entities to test and deploy their technologies. The collaboration mechanisms and issues encountered in working with these non-traditional stakeholders are very different from those involved in working with industry and usually entail unique case-by-case features. An example is given in the following case study.

CASE STUDY: The main data sources for U.S. severe weather warnings and forecasts of tornadoes and flash flooding are 159 National Weather Service (NWS) long-range radars. However, this system has coverage gaps, especially at lower altitudes. To address these gaps, the ERC for Collaborative Adaptive Sensing of Atmosphere (CASA) developed a paradigm to supplement the large radars by dense networks of small X-band radars. Traditionally, transfer of technology like this to the commercial weather enterprise was driven by NWS requirements and federal funding, but it has become hard for NWS to obtain the necessary funds. Therefore, rather than relying on federal resources, CASA has led a locally-driven model in which a regional catalyst brings together multiple private/public, local/national stakeholders to fund hardware and operational costs of a regional warning system. The goal is to create a replicable model for other U.S. urban areas. The platform for translational research and shared ownership is a 4-node radar network (expandable to 20 radars) that CASA is currently in the process of deploying in the Dallas-Ft. Worth (DFW) metroplex. Crucial to success of this research-to-operations effort is a contractual arrangement between CASA and a local organization known as the North Central Texas Council of Governments (NCTCOG). The NCTCOG brought together local towns and cities, stormwater departments, fire departments, TV stations, and local businesses to support the project. These organizations are bringing local resources (e.g., warehouse space, rooftops and towers for radar installations, network connectivity, electricity) at no cost to the project; they are also paying for installation and operations of the radar network and raising supporting funds through federal (e.g., FEMA) and state grants and local foundations. Members of CASA's Industrial Advisory Board, which include radar manufacturers, systems integrators, and NWS, are bringing additional funds or equipment. Managing this public-private-academic partnership is complex and requires frequent communication and coordination among the various stakeholders. If successful, it will demonstrate CASA's life-saving technologies in a densely populated metroplex and could lead to the installation of CASA radars all over the nation. CASA recently celebrated installation of the first radar in the DFW testbed at the University of Texas-Arlington with local stakeholders, who publicly welcomed the new CASA technology that will give them clearer, more precise weather information.

5.1.5 Involving Foreign Firms

NSF recognizes that an ERC can 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. The ERC must be diligent to assure that there is a true two-way and equitable flow of information between the ERC and foreign firms—the same standard as domestic firms. In 2012, about 22% of the 326 ERC industrial members were foreign firms. This is an increase from a decade ago, when the average was 10-13%.

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[1] Source: National Science Foundation, Dr. Deborah Jackson; 2012

[2] Attachment 5-A provides a key to ERC centers and their abbreviations for the convenience of the reader throughout the chapter.

5.2 Building an Industrial Constituency

5.2.1 R&D and Commercialization Strategies to Serve Industry

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 posing 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.

5.2.1.1 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 not been prevalent in this process in university research. It is essential that the ERCâ€™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.

At times, some ERC members may want to explore research directions that do not map perfectly onto the ERCâ€™s core research goals. It is the ERCâ€™s responsibility to meet this need by collaborating with these companies under other mechanisms, such as sponsored contract research or fellowship research. ERC industry members 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 as it pertains to multiple ERC partner institutions. This is discussed further in Section 5.3.2.9.

5.2.1.2 Balancing the Needs of University Researchers and Industry

Throughout the research, development, and commercialization process, it is important to balance the needs of industry and the university. Whereas a universityâ€™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 as discussed in Section 5.3.2.9. The terms of these documents are usually negotiated among the ERC, industry legal staff, and the university technology transfer office.

5.2.1.3 The Changing Roles of Academic and Industry Researchers in Commercialization

For ERC-generated IP, the ERC offers the option to license to the member firms. If a member firm exercises the option, then the technology may move directly to the firm or the firm may sponsor a translational research project, involving ERC researchers in the process but under IP arrangements specific to the project. In this case, the roles of the ERC project director or Principal Investigator 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 inventorship 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.

For IP that member firms do not license, the ERC may offer the license to a large firms with resources sufficient to explore further development of the technology; or, to a small firm (member firm or not). Because small firms do not have funds available to advance the technology, the firm may seek support from the ERC Programâ€™s Translational Research Fund under the annual Small Business/ERC Collaborative Opportunity (SECO) solicitation. In that case, the small firm submits the proposal with a subaward to the ERC. IP generated from sponsored project support and translational research project support under SECO does not revert to the IAB or the university.

5.2.2 Attracting Corporate Members

The need to attract new industrial 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 can belong to the center. These criteria deal with issues such as foreign firms and Multinational Corporations (MNCs), 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 some engage their members at long distance. This section addresses successful strategies for recruiting appropriate members.

5.2.2.1 Strategic Plan for Recruitment

The ERCâ€™s Industrial Liaison Officer (ILO) or Innovation Director manages this activity. Centers vary significantly in the formality of their strategic plan for recruiting member companies. Proactive approaches to industry member recruitment are highly recommended. As of 2013, the ERC Program Office requires ERCs to strategically plan to include the appropriate firms along the value chain most relevant to the ERCâ€™s engineered systems vision. In that way, the research is informed by the appropriate firms involved in the technologies underlying the system, as well as the system itself. In addition, these firms also find benefit in interacting across the ERCâ€™s value chain in the IAB. See Figure 5-1 for an example from CBiRC.

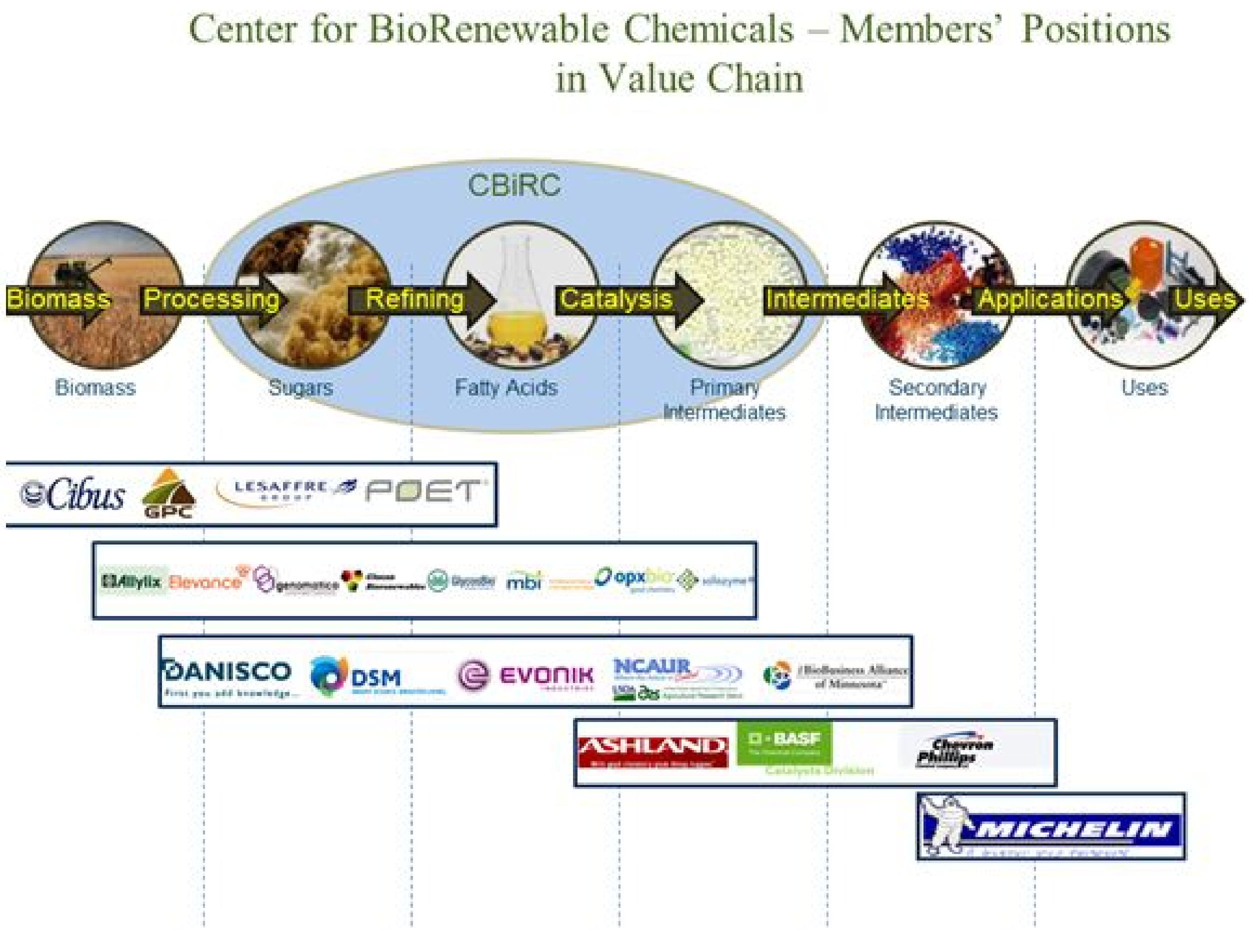

Figure 5-1â€"CBiRC Value Chain

Most ERCs 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.

5.2.2.2 Marketing the Center

An important component of the strategic plan for industrial interaction is a clearly defined marketing strategy for recruiting industrial sponsors. A well-developed marketing strategy typically includes an analysis of the industry sectors affected by the centerâ€™s research, the value chain, and the value drivers that industrial sponsors will find attractive in a research and technology transfer relationship. The marketing plan includes financial and technology commercialization goals, specific actions and timelines needed to reach those goals, and a budget for the Industrial Membership Program. This plan includes strategies not only for recruiting new members, but also for retaining existing ones through customer service activities such as communications of center research activities and results, faculty interactions with sponsor companies, interactions with students to gain know-how and recruit, and regular visits to sponsorsâ€™ sites.

Many ILOs have experience working in industry, but they also need to understand the academic culture and university/industry collaborations in research. The ILO position must be a full-time staff position reporting to the Director of the ERC. Selecting an ILO who is a staff member in the university technology transfer office, who might work part-time for the ERC, is not an effective strategy as the ILOs must first of all work for and promote the ERC.

Most ILOs 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 rises 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.

Advertising and â€œcold callsâ€• to potential sponsors usually are not productive. 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 members. 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 significant track record, it is a good idea to market the centerâ€™s program and vision. This approach can be particularly effective with companies that have been involved with other ERCs.

It is the high quality of research (and graduates) that is always most valuable to companies. An NSF study of industry member benefits provides insight into the value points and is presented in Section 5.2.4.1.

Every center uses its Director, staff, faculty members, and sometimes students in its marketing efforts, proactively or reactively. ERCs may also use consultants to contact potential sponsors to identify and explore areas of mutual interest. In any case, the ILO is primarily responsible for this marketing effort to industry and is challenged to call on all available personnel and resources, as discussed below.

Carefully identifying the companies that can benefit from the research in the centerâ€”that is, finding the right partnersâ€”is important in successful marketing. Presenting information about the centerâ€™s respected faculty members must be accompanied by clearly defining the value of center participation from the companyâ€™s perspectiveâ€”what is known as the â€œValue Proposition.â€• This is particularly difficult in industries with a poor track record for R&D funding. Marketing techniques include literature, newsletters and brochures (hard or softcopy); 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.

Centers disagree on the value of various printed materials in marketing, but most believe that personal contact at professional and trade meetings or other â€œnaturalâ€• venues and visits are very effective. Particularly valuable are visits to companies by teams comprised of center faculty, the Director, and the ILO. These visits not only introduce the center to a broad audience of company personnel; but also help the ERC understand the companyâ€™s products, business climate, and issues so that the value of ERC membership can be specifically defined. In arranging such a meeting, the ILO should gather in-depth information on the company, brief the Director and faculty, and set objectives for the meeting in advance. The Internet is a highly productive source of low-cost leads. Contacts come from companies referring to the center's website, social media such as LinkedIn, and search tools for industry specific needs that meet ERC foci.

Consider that it may also be in the best interests of existing industry members to join in the recruitment process to broaden the support base and intellectual breadth and depth of the industrial membership, and by extension the ERC. 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 might 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. For example, when Peter Keeling developed the Value Chain for the CBiRC ERC, it was clear to the IAB that there was an opportunity to diversify the membership by developing a recruiting campaign targeting various member companies across the whole value chain.

Finally, 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.

CASE STUDY: The Mid-Infrared Technologies for Health and Environment (MIRTHE) strengthened its industry outreach and marketing efforts through the addition of the â€œMedia Affiliateâ€• membership category. They currently have Media Affiliates that provide marketing and exposure for MIRTHE on an in-kind basis (e.g., free advertising or publishing articles on MIRTHE technologies and applications, subject to normal editorial criteria for publications). The Media Affiliates, in turn, benefit from a window into emerging technologies and new product applications. For example, one of MIRTHEâ€™s 2009 high school student summer interns wrote an essay about *her experience that was published in the Education section of Photonics Spectra Magazine. Other examples stem from the deployment of sensor systems into environmental testbeds, particularly in China and Ghana, which has provided excellent media content.*

5.2.3 Engaging with Industry Members

Key to a centerâ€™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 centersâ€™ experiences in engaging with industry members.

Maintenance of the company membership base and recruiting of new members is a continuing challenge, especially in times of economic stress in industry. 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 generally choose to spend their time in other pursuits.

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 issues important to some firms and the requirement that Ph.D. students focus their research on longer-term, higher-risk areas;
- Dealing with the imbalance among sponsors' views of desirable long-term research directions; and
- Ineffective communication with upper-level management in sponsoring companies.

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. 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 that will become members of the ERC as opposed to sponsoring research in the facultyâ€™s laboratories. 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 faculty interests and those of the company researcher must be aligned and clear to both parties.

5.2.3.1 Effectively Engaging Industry Champions

It is important to develop one or more champions within each company. Usually these will be firmsâ€™ 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 championâ€”preferably in a senior executive position at the companyâ€”makes the difference between a strong corporate member and a *pro forma*, uncommitted one. 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. Having two or more champions is of obvious benefit at such times.

Because ERC / industry member activities are both technical and managerial, many ERCs have industry member liaisons that come from both those groups within companies, and in many cases from different groups within companies. This is an excellent practice, as ERCs are well served by engaging multiple internal champions within companies to best spread the impact of the ERC and establish redundancy in contacts should one champion leave the company. Engaging strong management as well as technical contacts in companies is a solid strategy to assure that company technical and business-oriented needs are being fulfilled.

In considering effectively engaging champions under the structure of an Industrial Advisory Board, several guidelines can be offered. First, it is important to remember that it is an advisory body. Final decisions must remain with the center management, and specifically the ERC Director. 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 advances 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.

5.2.3.2 Information Exchange with Companies

One challenge of ERCs 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 companyâ€™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 companiesâ€”a strategy that is substantially aided through electronic communications. 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 companiesâ€™ internal email systems to share information. Others are using electronic forums and video-conferencing as ways to broaden awareness.

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. Agendas for these meetings should include significant time for industrial participants to interact with the material and its presenters. The traditional academic one-hour presentationâ€”with an introduction, methods, results, summary, and conclusionsâ€”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. 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 applications 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 number of 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 cost in membership fees. Some centers use hotel meeting facilities, while others hold the meetings at university sites. In any case, proximity to ERC facilities allows tours and laboratory visits to be included, either formally or informally.

Centersâ€™ meetings with Industrial Advisory Board members vary considerably, but are usually 1-2 days long. The Chair of the IAB organizes the meetings, serves as a chair for each meeting, and works with the members to set the agenda. 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.

For the IAB meeting that is contiguous with the ERCâ€™s NSF site visit, the IAB members need to attend the ILOâ€™s briefing of the site visit team (SVT) and then devote an hour to meet with the SVT in private to present their SWOT analysis of the center to the SVT and discuss their mutual findings. The ILO and Center Director are not present at this meeting because NSF and the IAB meet as joint funders of the ERC. 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 NSFâ€™s most important measures of the centersâ€™ performance. The purpose of the SWOT is to:

- Analyze the *strengths* and *weaknesses* of the ERCâ€™s vision, strategic plan, research, education, industrial collaboration, leadership and team, and management system;
- Identify any *opportunities* for the ERC to increase its impact; and
- Identify any serious *threats* to the ERCâ€™s ability to fulfill its vision; these include both internal and external threats.

Industry members summarize the results of the analysis in bulleted slide presentations, for the use of the NSF annual Site Visit Team and the ERC leadership. The ILO and IAB chair have to determine how best to develop the SWOT analysis so that it is ready for the annual site visit presentation. The IAB Chair, at least, also will discuss the results of the IAB SWOT with the ERCâ€™s leadership team.

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 industryâ€™s priorities and concerns.

The second IAB meeting, about six months after the first, will include separate research reviews (â€œERC Research Daysâ€•), the agendas of which vary from center to center. Typically such a review is held during a 1Â½- to 2Â½-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 this is combined with lunch or a buffet supper); and industry feedback sessions. Some centers use the â€œrawâ€• 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. This type of meeting is necessary for the IAB to be able to provide input on the progress of ongoing projects and the plans for new projects.

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.

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.

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 with 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 membersâ€”in essence, their internal advocate. Undertaking this role makes the ILO an invaluable resource to members and serves the purpose of the ERC in fostering closer industrial collaborations.

5.2.3.3 Industrial Input into Strategic Planning

Strategic planning for the center's research, education, diversity, 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.

CASE STUDY: CCEFP introduced the Technology Readiness Level (TRL) system to its industry members as a tool for program and project management. The TRL system was originally developed and refined by the US Department of Defense (DoD) and NASA to define the maturity of a technology. It is widely used in both agencies. TRL numbers range from 1 to 9. A project rated TRL 1 is the least mature (it could be just an idea or a sketch on a napkin) and TRL 9 represents full commercialization. Projects above roughly TRL 4 are moving from pre-competitive to competitive, so when Center research projects reach this level they are â€œgraduatedâ€• (i.e., Center funding is stopped). The technology resulting from the research can then be transferred to industry directly or matured through a directed / sponsored project partnership between industry and the PI. The use of the standardized TRL terminology has provided a common language that makes communications about the maturity of a project much easier. The use of TRL assessments for project review, selection, and tracking provides a clear means to show progress of a project toward commercialization and a projectâ€™s maturity relative to other Center projects. It also helps explain the so-called â€œValley of Deathâ€• that exists between the pre-competitive research done at an ERC (generally progressing up to TRL 4) and the level of technology readiness at which industry is typically interested in using significant internal resources to commercialize a product or technology (typically TRL 6 and above). The TRL structure utilized by CCEFP (adapted from the DoD TRL) is shown in Figure 5-2.

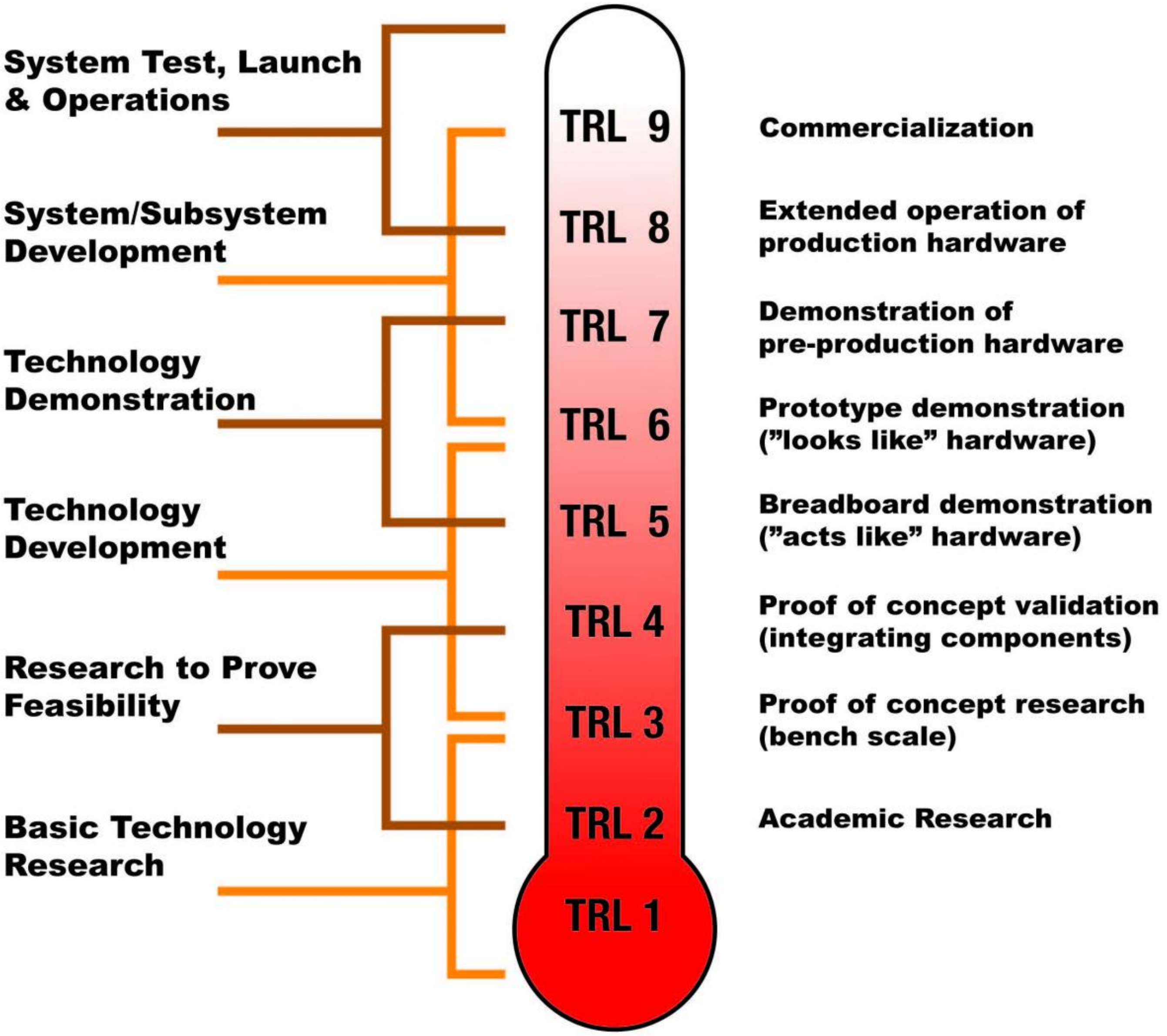

Figure 5-2. CCEFP Technology Readiness Levels

5.2.3.4 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 â€œhealth club analogyâ€• with industrialistsâ€”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 in industry
- Extended visits to the ERC 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.

CASE STUDY: The MIRTHE education program reflects strong industry connectivity. Every August there is a weeklong Summer Workshop that is held on a core partner university campus, on a rotating basis, and culminates in an industry/student networking dinner on the last day. During the workshop, students are the lead organizers for a "students-only" afternoon that provides opportunities for MIRTHE students to present research to the IAB and SAB. The Student Leadership Council (SLC) facilitates student meetings with the MIRTHE program evaluators and has significant input on the choice of career workshop speakers. Also, the SLC advises the faculty on how to choose the best student papers and posters and its members are often tapped to chair student-related sessions.

5.2.3.5 Industry / University Collaborative Research Teams

ERCs have found that close, personal liaison and one-to-one collaborations between faculty and students with industrial sponsors at the project level 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 encouraging research done cooperatively with industry.

In some centers, research collaborations have extended to groups of companies, consortia, and other universities. 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.

CASE STUDY: At the Rutgers University-based C-SOPS, industry mentors are integrated at the project level. Industry mentors are invited to co-mentor students and postdocs on all projects, and matches are facilitated by C-SOPS. Companies designate specific personnel to serve as mentors, with the number of mentors determined by the level of participationâ€"Level 1 sponsors have several mentors; Level 2 sponsors are limited to two project mentors. Each project has multiple industrial mentors, with one serving as a lead mentor. Roles are clearly defined, including communication and progress standards. Mentors provide formal assessment of specific project progress at IAB meetings to focus on results and deliverables. Mentoring allows for input at the industry â€œgrassrootsâ€• level within a company, while maintaining upper-level strategic involvement at the IAB level. Mentoring with the testbeds may play a critical role as these are closer to commercialization, and industry involvement may play a translational research-to-development role. There are distinct pluses, downsides, and challenges to this model. Pluses: The industry mentor has a vested interest in solving a process or manufacturing problem and technology partners are engaged, since the project is focused on their future product. This distributed model of industry engagement makes it more valuable to companies, as interactions are not limited to one person within the company (both high-level strategic and â€œgrassrootsâ€• engineering support). Companies often have meetings to bring together all of their mentors participating in projects. The value of the overall engagement can be communicated to upper management, thus making participation in C-SOPS more tangible to upper management. Downsides: Creation and management of the mentor activities is very time-consuming. Discipline may lag at *critical periods if teams have scheduling challenges. There tends to be more one-way communication from the center to industry, and this may not be as interactive as desired, since most of the team meetings are done via teleconferences due to restriction of industry travel. In some cases, certain industry personalities may dominate. Challenges: The IP protection process is challenging with outside mentors closely involved in projects. On the flip side, the industry mentors may be too close to what they are doing within their company, and may remove themselves from projects to protect the companyâ€™s interests or intellectual property.*

5.2.3.6 Tracking Interactions with Industry and Innovation Partners

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 innovation programs. ERCs and NSF regard this capability as vital to any centerâ€™s success. A customized database or commercially available contact tracking software package 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.

CASE STUDY: SynBERC has created an in-house electronic (web-based) project proposal submittal and review tool that captures all relevant information in a very concise and complete way. There is a separate, excellent review and scoring process to go along with this â€œProject Centerâ€• and it gives a good overview of the SAB and IAB view of the overall proposed project portfolio to guide the Leadership Team in funding decisions. Other ERCs have adopted similar systems based on the SynBERC model.

5.2.3.7 Balancing Long- and Short-Term Research

Despite industry's perennial need for short-term problem-solving, several centers reported few problems in matching long-term university research with industryâ€™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.

**CASE STUDY: The RMB program management system helps the ERC to assess the balance of basic and applied research efforts, putting each project into a progress- or milestone-driven process. This helps RMB to assess each project from quarterly reports for progress and deliverables, keep track of student advancement, determine when projects may begin to intersect or align, and it provides a mechanism for determination of go/no-go decision points. Not only does the project management system drive research progress, but it also provides an â€œefficiency frameworkâ€• for faculty to operate within, creates parity and transparency in funding decisions, and supports an educational environment for student development relevant to industry. This also is a system that allows industry to offer input at critical research decision points, and can point a project towards a market opportunity not previously imagined.*

5.2.3.8 Industry Support for Consortia vs. Directed Research

At times, industry tends to move away from supporting academic consortia in favor of directed sponsored research. A commonly heard company argument is that with tight industry research budgets, companies must focus scarce resources on:

- a list of favored universities for each company (usually top-down driven), and
- specific researchers who are well known in their field and are doing work that is specifically targeted toward the companyâ€™s interests (usually industry researcher / bottom-up driven).

With that said, industry seems to understand the significant benefits of leveraging the NSF investment in key fields of development, as evidenced by the large number of companies supporting ERCs. An ongoing challenge for the ILO is keeping industry engaged in longer-term research wherein specific benefits to the company are not clearly demonstrable. This is the same issue that ILOs have faced since the inception of the ERC program and is inherent in a program that balances basic research with industrial collaboration.

ERCs may see more opportunities to partner with industry in innovation-focused research proposals jointly submitted to federal funding agencies. The ILO and Associate Director for Research or Thrust Leaders should survey leading agencies for such opportunities, as funding for innovation and translational research is a growing opportunity.

5.2.3.9 Measuring Program Effectiveness

Metrics used to assess the effectiveness of the industrial collaboration and innovation programs vary among the different centers, but NSF does have some common expectations, as discussed here and required by NSF in the ERC's annual report. Other metrics 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 companiesâ€"what was adopted, how it was used, the impact on the company and on the industry, and other indicators. Data quantifying the impact are especially powerful. In all cases, success "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 centerâ€™s own use, this information is used by NSF for a variety of purposes. Metrics used in ERCs can 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 and in-kind corporate contributions;
- number of companies attending center meetings;
- number and industrial collaborators on projects; and
- number of faculty visits to companies.

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.

As discussed in Section 5.2.3.2, industrial members perform an annual SWOT analysis. Additionally, each centerâ€™s students perform a second, parallel SWOT analysis. Members of the ERCâ€™s Student Leadership Council gather and synthesize input from participating students (as both participants in and customers of the ERC). Students use the same criteria and techniques as those of the industry membersâ€™ SWOT analyses. Like their industrial counterparts, they communicate the analysis to the NSF site review team and the ERCâ€™s leadership for the purpose of continuous improvement

CASE STUDY: CBiRCâ€™s SLC has an especially strong SWOT (strengths, weaknesses, opportunities, threats) analysis protocol that exposes, from student perspectives, critical issues relating to how well the ERC is achieving its goals. The annual analysis, which partners students, ERC leadership, and the NSF to strengthen the enterprise, is designed to mitigate the influence of individual (one-off) opinions that might not be shared by the larger student group. The analysis has five main steps: (i) brainstorming to generate question topics (e.g., the ERC's collaboration with industry is a strength?); (ii) analyze results to create key questions for survey; (iii) survey students (e.g., strongly agree/agree, no opinion, disagree/strongly disagree); (iv) analyze results (quantitatively and qualitatively to assess all student responses); and (v) present findings to the ERC and NSF. An example of how findings can be *presented is as follows: student responses indicated that "lack of scientific knowledge being shared by industrial partners" was a CBiRC weakness in 2011 (44% strongly agreed/agreed, 27% had no opinion, and 29% disagreed/strongly disagreed). Action items can be derived from stated weaknesses (e.g., ways to strengthen opportunities for internships). Additionally, results from prior years can be compared to current-year results to assess progress (e.g., have communication and collaboration with industry increased?). In summary, this type of SWOT analysis can be very informative in communicating to ERC leadership and the NSF regarding the overall health of the ERC.*

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 non-measurable (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?"

5.2.3.10 Start-up and Small Company Challenges and Opportunities

Identifying mutually beneficial relationships with start-up firms and small companies has specific challenges for most centers. These companiesâ€™ small R&D staffs and immediate product concerns often hinder them from participating proactively 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 may not benefit from full membership in a center when considering the membership fee and time commitment. Nevertheless, in high-risk research areas such firms may represent an important mode of technology commercialization. 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 partnershipâ€”especially with a government agency focus on innovation in solicitations.

Care must be taken to manage conflicts of interest for any spin-off firms that involve the ERCâ€™s faculty, executive managers, or ILOs. The ERC must develop a conflict of interest (COI) management plan with the university COI officers.

The ERC must be diligent that small and large company engagement is perceived as equitable. One concern is that larger companies may be reluctant to contribute a substantially larger cash or cash / in-kind investment with an ERCâ€™s perceived focus on smaller company-focused innovation and technology commercialization programs. Additionally, some ILOs have voiced concern that the focus and time spent on engaging small companies can tend to decrease the ERCâ€™s overall industrial membership fees, as small companies typically pay less than large-company fees for equivalent benefits, especially access to IP. Clarity as to the expected mix of large and small company focus for each ERC should be carefully considered, as each centerâ€™s potential industrial support base is unique and sometimes quite dissimilar from other centers (e.g., biotech/emerging medical technology vs. electronics-focused centers). Above all, the industry and innovation partners need to perceive as equitable the industrial partnership and fee structure and the opportunity to leverage ERC technology outputs to the benefit of the partner.

Longer-term engagement of small companies, especially in difficult economic times, can be less stable than for large companies, as trimming of whatâ€™s sometimes perceived of as â€œnon-essential activitiesâ€• spending is usually the first step in retaining capital for core functions. This can lead to higher small-company turnover and therefore more time spent in recruiting new companies. These concerns can be valid in that the ILOâ€™s time is typically stretched, especially with the added innovation duties of the Gen-3 centers, and ILOsâ€™ need to prioritize their recruitment attention and time.

Most states have innovation 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) or Small Business Technology Transfer (STTR) 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 (www.ssti.org), a nonprofit research and education organization that tracks such state programs and monitors the state-federal relationship in science and technology.

5.2.4 Benefits and Challenges of Interacting with ERCs

Studies of ERC industrial sponsorsâ€™ satisfaction with and benefit from the ERC programs were completed in 2004[1] and 2012[2] and the results provide a clear view of the benefits and challenges of industry interacting the ERCs that is instructive to ILOâ€™s and other center leadership. This section will highlight the major findings of those studies, but the reader is directed to the referenced reports for further detail.

5.2.4.1 Benefits to Industry of Engaging with ERCs

Overall, both studies found that ERC industry members were generally very satisfied with the ERC programs. The 2012 study found that almost 90% of the members felt that their expectations of the ERC had been met or exceeded and in both studies, approximately 75% of industry respondents felt that the benefits received matched or exceeded the financial commitment that they had made to the center. While the entire ERC package (research, education, outreach, industrial collaboration, innovation) is designed to support industry, a more granular look reveals the specific benefits that industry values.

The 2012 study confirmed that industry members recognize the strengths of the ERC IAB model for a number of reasons. Industry felt that the ERC systems-level approach and industrial consortium model kept a focus on cross-disciplinary research in complex fields that addresses important problems in industry and gives industry input into how best to direct the NSF funding. Additionally, industry valued the ERCâ€™s ability to work on pre-competitive research that brings together scientists and engineers (from sometimes competing companies) with academic researchers to advance technology. Ultimately, the study showed that industry valued their participation to improve the chances that the technology will transition to industry and be scaled up. In addition, they valued development of the talented young ERC researchers/students in preparation to joining industry.

A company makes a decision to join and maintain membership in an ERC based on its expectation of benefits. It is important for the ILO and center leadership to understand industryâ€™s specific expectations in order to highlight these benefits as part of the centerâ€™s marketing efforts. The 2012 study queried industry sponsors as to the single most important factor influencing the companyâ€™s decision to join the IAB, as well as the three most important factors. The cumulative responses to both questions were very consistent and so only the survey results regarding the three most important factors in joining the ERC are given here, but the reader is again directed to the report for further detail. Industry members identified their three most important factors influencing the companyâ€™s decision to join the IAB as:[3]

- Follow developments in a field related to my companyâ€™s business (61%)
- Support advances in a technology space important to my company (53%)
- Gain access to specific expertise resident in the ERC (37%)
- Establish relationships with ERC faculty (33%)
- Network with other IAB members (28%)
- Evaluate students as potential employees (26%)
- Leverage company resources through collaborative research (23%)
- Access ERC developed intellectual property (19%)
- Seek partnerships with other IAB members (11%)
- Gain access to ERC facilities / equipment (9%)
- All other responses (5%)

The 2004 study showed similar findings of industry benefits as the 2012 study. In the 2004 study, industry members were asked to estimate the relative importance of specific reasons for their firm joining the ERC. That study indicated that the most important reason for joining the ERC was access to new ideas and know-how (rated by 78 percent of respondents as very or extremely important), followed by access to faculty and to ERC technology, and then by prior connections or relationships with individuals at the ERC.

Of significance in the 2004 study, 40% of industry members reported that they had hired center students or graduates. Among those industry members who received benefits, the value of hiring students or graduates was rated more highly than any other benefit studied. On every one of a wide range of performance criteria shown in Figure 5-3, a large majority of ERC students or graduates hired were rated somewhat or much better than comparable non-ERC hires.

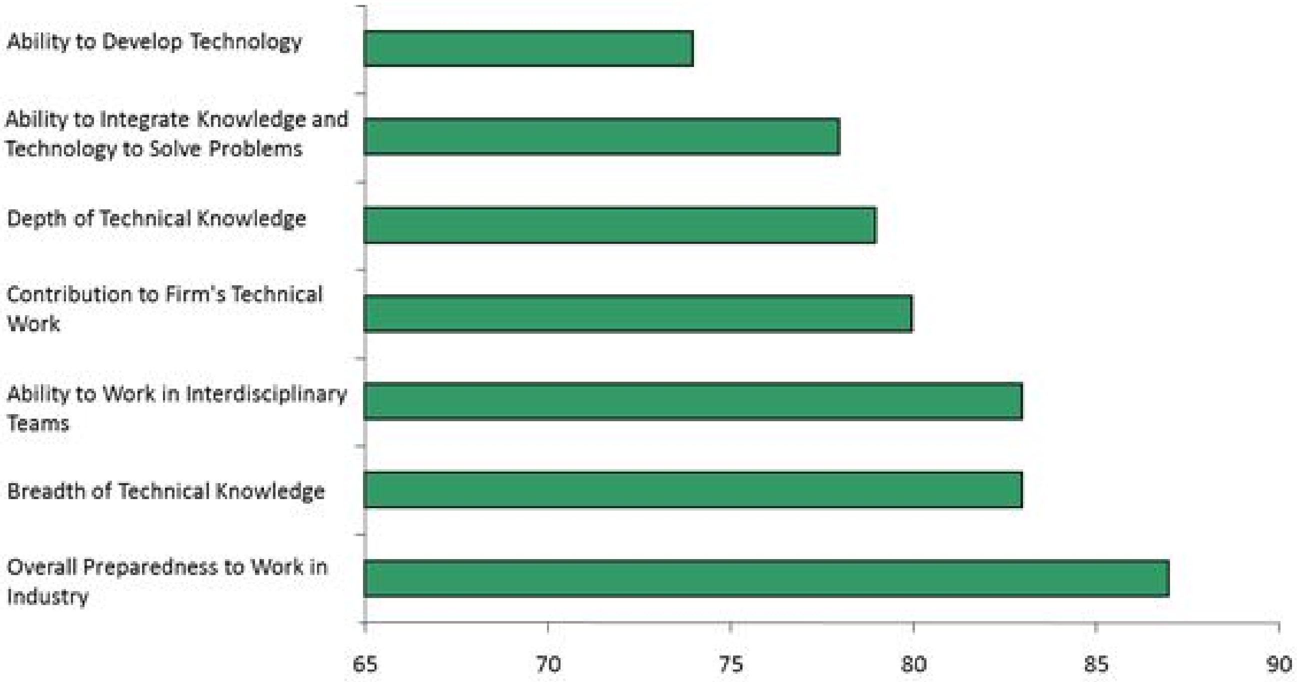

Figure 5-3â€”Percentage of industrial supervisors rating the former ERC students / graduates hired by their firms as â€œBetter Thanâ€• or Much Better Thanâ€• equivalent hires without ERC experience.

The message to ILOs is to encourage industry members who hire ERC graduates to get the message out to the other companies regarding the value of these students, and for the ILO to carry this message to new companies they are recruiting.

Industry members in the 2004 study were also asked to identify and rate factors that might contribute to the benefits their companies gained from ERC participation. The top factors that were rated as very or extremely important by the highest proportion of representatives (between 48% and 53%) were:

- The continuous existence of a strong ERC â€œchampionâ€• in the company unit (53%);
- Responsiveness of ERC faculty/researchers to our needs (51%);
- Management support of the ERC within our company (49%);
- The closeness between the ERCâ€™s specific technical focus and ours (48%); and
- The ERCâ€™s efforts to communicate and stay in contact with sponsors (48%).

ILOâ€™s should take note each of that these top factors can be heavily influenced by the ERCâ€™s leadership, with the ILO as the point of contact, putting in place a sound industrial member retention strategy.

When considering the barriers to companies receiving benefits from their ERC membership, industry members overall felt that the ERC consortium model was effective in that none of the barriers presented extreme difficulties for most members. â€œOther company mattersâ€• (45% of respondents) and â€œdifference conceptions of timeâ€• (38% of respondents) were the most significant barriers identified.

When one considers the time and effort typically spent on discussion of IP clauses of the Industry Membership Agreement when recruiting a company, itâ€™s interesting to note that access to ERC-developed intellectual property ranked relatively low compared to the value that companies put on more general benefits such as following development and supporting advancements in the companyâ€™s field, according to both the 2004 and 2012 studies. The 2004 study showed that 90% of industry representatives reported gaining access to ideas and know-how, 60% reported improving or developing new products and processes, while only 15% licensed center-produced technology or software. Additionally in the 2004 study, the ability to license inventions or software developed by the ERC ranked as one of the least important reasons given to join the ERC (along with access to equipment, facilities, and/or testbeds and the ability to leverage the firmâ€™s research investment with money from other ERC sponsors).

General experience (time in the trenches) can provide guidance to new ERC industry members as much as studies. In order for industry to gain maximum benefit from their partnership with the ERC, the following best practices guidance for industry from Gen-II ERCs is provided:[4]

- Early and long-term engagement enables members to reap the most rewards; do not sit on the sidelines as an affiliate. This has been proven through Gen-II and now Gen-III ERCs. The level of active industry member participation over years of membership is directly related to benefits accrued.
- Active participation in strategic planning, providing guidance on research and education through the IAB, brings relevance. As shown in the referenced studies, both industry and the ERC gain significant benefits in high level, long-term partnerships to guide the centerâ€™s strategic plan.
- Bring students to your firm for ERC-relevant internships. ERC students are different in terms of their skill sets and experiences; and these differences can be leveraged by companies that actively engage with these students early in their academic careers.
- Become a champion for a thrust or a testbed. Nothing engages and impacts like active engagement and championing of a specific project. Get in the trenches.
- Provide sponsored project in addition to membership support for the most payback to the firm. Companies who benefit most understand that the value of the research and education goes beyond core research. Companies can tailor results to their benefit through support of directed research that builds on the ERC core research base.

5.2.4.2 Benefits to the Center of Industrial Involvement

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.

As the ERC-Industry partnership adds value to industry members, so it also adds significant value to the ERC. The 2012 study highlighted the breadth of benefits that center directors and ILOs felt were gained from the IAB. ERC Membership Advantages for the ERC as reported by the center leadership included:

- The ability to pursue small development projects to help vet and advance some premature technologies towards commercialization;
- Support for industrial outreach efforts;
- The ability to expand educational outreach and support for special ERC projects (e.g., testbed expansion);
- The ability to increase the number of students and postdocs that are funded; and
- The ability to hold workshops on specific topics of interest to industry.

The 2012 study polled center leadership as to the single most important area where additional guidance from the IAB is needed, as well as the three most important areas. As with the benefits to industry results, the responses to these queries were similar, so only the three most important areas where additional guidance from the IAB would aid the ERC are reported here. Those areas were (with the percent of respondents):

- Technology road mapping / strategic research direction (54%);

- Sustainability planning (46%) (note: 33% of the ERCs polled were older than six years);
- Understanding how to position technology in the marketplace (31%);
- Technology assessment (23%);
- Support for internships (23%);
- Referrals for partnerships (23%);
- Market assessment (15%);
- Enhancing technical capabilities (staff, equipment, etc.) (15%);
- Student preparation for research in an industrial setting (15%);
- Understanding ERCâ€™s value proposition to industry (15%);
- Understanding the competitive environment (8%);
- Entrepreneurship training (8%);
- Support for seminars and workshops (8%); and
- Developing center messaging (8%)

Studying these benefits through the referenced report is instructive to ILOs in confirming that industry serves a key role for the ERCs in high level, longer-term functions (e.g., technology road mapping, sustainability planning) as well as shorter-term functions (e.g., technology assessments, internship support). ILOs should keep this in mind as they best engage their industry members to forward the ERC mission and programs.

The 2012 study also informs on the avenues for the most helpful guidance from IAB members. While input from industry members should and does come in many forms, center leadership felt that the maximum value of industry member input is provided (on a scale of 1-6, with 1 being the most useful):

- in private conversations (2.15);
- during IAB meetings (3.0);
- through conversations between IAB members and the ILO (3.54);
- during one on one discussions with the ERC management team (3.85);
- from the IAB SWOT (4.15); and
- during one-on-one discussions with project teams (4.31).

5.2.4.3 Benefits of the ERC to the University

It is important to recognize that the universities are perhaps the greatest beneficiary of the NSF ERC Program. Todayâ€™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 are becoming more effective in learning how to work efficiently with industry, and the ERCs have led 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 various departments involved in university administrationâ€”especially in coordinating R&D contracts, IP management, and commercial licensing.

- An R&D consortium, built over many years, is an â€œinstant marketingâ€• system comprising a set of well-informed partners (as opposed to a series of one-at-a-time and one-to-one handoffs)â€”the consortium partners will tend to â€œpull on the rope,â€• 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, as the scientific enterprise in such a highly coordinated, multidisciplinary system is an enormous drawing card to the best engineering researchers[5]

5.2.5 Driving Toward Self Sufficiency

NSF supports the ERC program to provide international leadership in engineering research, education, outreach, and innovation that goes well beyond the NSF ERC funding cycle of 10 years. It is the Foundationâ€™s intent that the NSF funding be catalytic and result in growth in center programs to the point that other entities (e.g., industry, universities, and other federal programs) will sustain the centers to serve future generations. As such, the ERC team, under the leadership of the Director and ILO, need to plan for self-sufficiency from the early years of the centerâ€™s life.

A clearly defined value proposition can be a key to success in retaining members in the drive to self sufficiency. How each ERC chooses to articulate its specific value proposition, it must show how the center can provide substantial benefits to stakeholders, especially industry, beyond the NSF funding cycle. Industry needs to understand that the ERC can continue to provide financial impact; knowledge; technology; talent; and relationships.

A 2010 NSF-commissioned study of graduated ERCs[6] found that 83% of the then-35 graduated ERCs are self-sustaining. Several major factors contributed to this high rate of ERC self-sufficiency post the NSF funding cycle and a review of major findings with regard to successful transition of ERCs to self-sufficiency is instructive:

- Broad involvement of faculty, staff, industrial partners, and university administration in transition planning is critical. Self-sufficiency, which includes replacing substantial NSF support (financial and otherwise), is not a trivial challenge and all stakeholders need to be engaged and brought into the process from an early stage. Effective implementation of a realistic transition strategy that builds on and enhances the centerâ€™s strengths is key. While the Centerâ€™s attention will be focused on forming and growing programs in the early years, a realistic self-sufficiency plan should be crafted, with input from all stakeholders, prior to the sixth year review.
- Institutional factors such as the degree of university commitment, the extent to which the center is prized, and whether or not the centerâ€™s policies support cross-disciplinary research and education, are critical. The ERC should be a leader on campus in terms of establishing a systems-level approach to research and development, fostering research and education collaborations with industry, and building strong innovation programs. These should serve as templates for other programs to establish the â€œERC cultureâ€• across the partnering universities.
- At the end of the NSF funding cycle, the education, outreach, and industrial collaboration programs are typically under the most stress, since the research program can to a degree rely on more traditional funding sources for a university. In order to maintain a true ERC culture, these programs, especially education, must be sufficiently valued by faculty and students such that they will be maintained. This usually requires a core group of faculty dedicated to these functions.

Maintaining the active participation of industry post NSF funding is difficult and requires a redoubling of efforts by the center leadership. Retaining the ILO is critical. Companies that have ERC graduates as valued employees will feel a greater allegiance to the center and will have a greater self-interest in its continuation. It is key to use the early and growth years of the ERC to foster industry champions who believe strongly in continuation beyond the NSF funding cycle. A history of having involved industrial members closely in the centerâ€™s strategic planning of research, in joint research projects, and successful transfer of technologies that have been valuable to companies in product/process commercialization are crucial factors in convincing industry to remain in the center following graduation. Around Year 5, it is important to begin discussing with the IAB the eventual cutoff of NSF funds and to involve them in the centerâ€™s self-sufficiency planning as valued partners in the continuing life of the center.

CASE STUDY: IPrime was formed in 2000 from successful industrial collaborations begun under the Center for Interfacial Engineering (CIE), which operated at the University of Minnesota with NSF funding from 1988 to 1999. IPrime is now self-supporting based on substantial annual membership fees from m,ore than 40 diverse, large and small industrial partners. IPrime focuses on collaborative two-way knowledge transfer and provides important benefits to its members by offering a â€œone-stop-shopâ€• entry point for industrial connections to the university research infrastructure (numerous faculty plus several technology departments and research program areas, some still supported by NSF-funded Materials Research Science and Engineering Center activities). IPrimeâ€™s Director reports that the groundwork for successful transition from ERC status to self-supporting operation must be *established long before an ERC is ready to "graduate." In his view, key elements of that early groundwork include: (a) broad coverage of technologies of interest to industry; (b) an Industrial Fellows program, which consists of scientists from industry who are resident on campus for a time to work on a research project of mutual interest with a faculty member and perhaps graduate students; (c) ability to solicit and act expeditiously on industrial input; (d) Technical Advisory Committees, through which companies can influence the general direction of university research programs and also suggest research that they would like to see but do not have the time or resources to pursue; (e) mutual faculty and industrial interest in continuing interactions, including expressed faculty interest in applied science as well as basic science; (f) senior faculty modeling of successful interactions with industry in order to train younger faculty; and (g) staff that embraces the industry-oriented customer focus, that makes it easy for industry to do business with the ERC (e.g., approaches that minimize legal wrangling), and that understands R&D management issues. IPrime's experience demonstrates that graduated ERCs can retain a strong industrial partner base if the necessary factors are in place beforehand. The end result, demonstrating tangible benefits for both university and industrial organizations, is a "win-win" for both sides -- complementing industry as well as the enduring elements of the former ERC. [For more information, see: www.iprime.umn.edu.]*

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[1] The Impact on Industry of Interactions with Engineering Research Centersâ€"Repeat Study; SRI International: Arlington VA, December 2004.

[2] IAB Involvement in ERCs: Assessing and Strengthening the Role; Peter Seoane; presented at the NSF ERC Annual Meeting: Washington, DC, November 2012.

[3] Percentages shown are those companies identifying that benefit as one of their top three.

[4] Best Practices for Industry Members of an Engineering Research Center; 2012 ERC Startup Briefings Presentation; Lynn Preston, Leader of the ERC Program: NSF, November 2012.

[5] See, for example, Impact of ERCs on Institutional and Cultural Change in Participating Institutions, SRI International: Arlington VA, June 2001.

[6] Post-Graduation Status of National Science Foundation Engineering Research Centers, Report of a Survey of Graduated ERCs; SciTech Communications LLC: Melbourne FL, January 2010.

5.3 Building an Innovation Ecosystem

5.3.1 Defining the ERC Innovation Ecosystem

The ERC Gen-3 Program rest on the core key features of the historic (Gen-2) program and adds innovation features. However, a primary mission of the Gen-3 ERCs continues to be industrial collaboration and technology transfer to member firms. This is augmented by a focus on innovation and entrepreneurship for students and a reliance on small firms to carry out translational research when member firms fail to license ERC-generated IP. In addition, Gen-3 ERCs are required to build partnerships with innovation facilitators (university and/or state and local government organizations devoted to entrepreneurship and innovation) to help accelerate the transfer of ERC technology to the marketplace when member firms are not involved in that process.

Thus the original mission of the ERC Gen-2 industrial collaboration program is to build a strategic industry alliance to develop and deploy new technology. This is the primary industrial mission of Gen-3 centers as well. The Gen-3 small firm component and the innovation facilitators are additions to that original mission.

The overall strategy for innovation and technology commercialization can best be described by the following narration from Dr. Deborah Jackson, and ERC Program Director in the NSF ERC Program Office.

â€œMoving innovations from discovery through to commercialization involves numerous actors, often including academic researchers, small businesses, the investor community, and commercial industry. At one end of the spectrumâ€”academeâ€”there is a heavy concentration of government investment in fundamental research. At the other end, in the commercial marketplace, there is a much higher level of industry investment in direct product development. In between lies the so-called Valley of Death, where many potential innovations die for lack of the resources needed to develop them to a stage where industry or investors can recognize and exploit their commercial potential. Crossing that valley requires a complex interplay of relationships along the innovation spectrum. Common approaches include creating formal vehicles for collaboration, such as non-disclosure agreements and memoranda of understanding, or creating opportunities for actors to circulate among different entities through visiting-scientist or post-doctoral programs, sabbaticals, or consultant arrangements. Additional vehicles for promoting interactionâ€”topical conferences, cross-disciplinary institutes, or centers of excellenceâ€”create the intangibles of the innovation ecosystem, improving the odds a venture will succeed.

Beyond the intangibles, one-time investments in the innovation infrastructure by the government can make the overall operation more efficient and thus either help lower the threshold cost to industry of launching new ventures or remove obstacles to reduce the time to market. These investments may include physical infrastructure, such as rapid prototyping facilities, or bundled start-up and intellectual property legal services that are accessible to most players in the ecosystem. Lowering the threshold cost and reducing time to market result in more ventures successfully crossing the valley and entering the marketplace.â€•

This philosophy is illustrated in Figure 5-4.

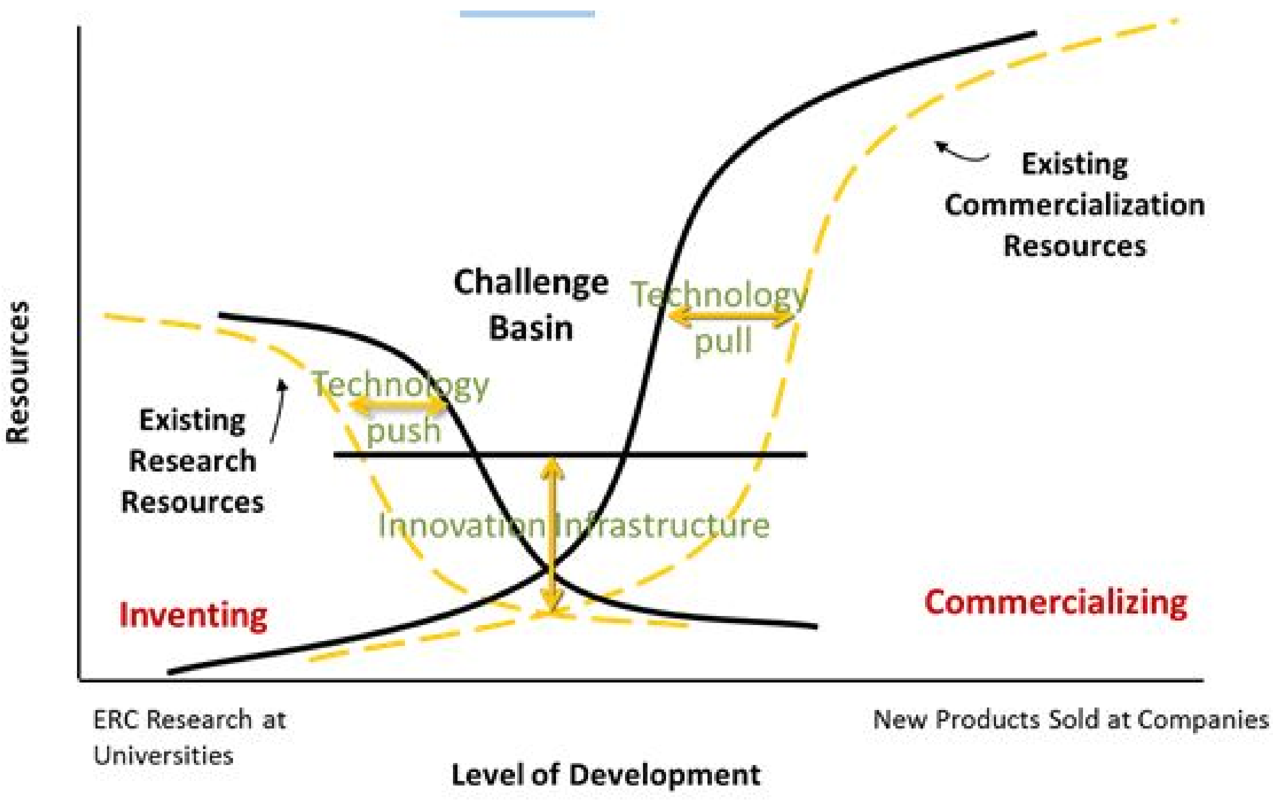

Figure 5-4â€”Innovation Bridge Structures Turns the â€œValley of Deathâ€• into a more approachable â€œChallenge Basinâ€• [1]

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 an ever-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 that is not licensed by ERC members. 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. Technology transfer takes the forms of directly commercializable technologies as well as the transfer of ideas, which industry can refine and cultivate into saleable products.

5.3.1.1 The Virtuous Innovation Cycle

NSF provides guidance on some of the critical success factors and infrastructure needed to establish and grow a strong innovation ecosystem, and these factors feed directly into a complete ERC industry communications and marketing program.[2] The ERC structure has a strong focus on industrial collaboration and innovation, bringing together necessary resources and talent to build a â€œvirtuous innovation cycleâ€• that combines the strength of the â€œResearch Economyâ€• and the â€œCommercial Economy.â€• ERCs are uniquely positioned to engage resources from both of these economies to push technologies from the research spectrum as well as pull technologies to market applications from the commercial spectrum. This combined push-pull strategy relies on the coordinated application of resources (funding, talent, innovation champions, educational programs, etc.) from both economies and a well-articulated and delivered industry communications and marketing program will clearly illustrate the value to industry and innovation partners of engaging with the ERC and translating technology and talent from the academic to the private sector. This is illustrated in Figure 5-5.

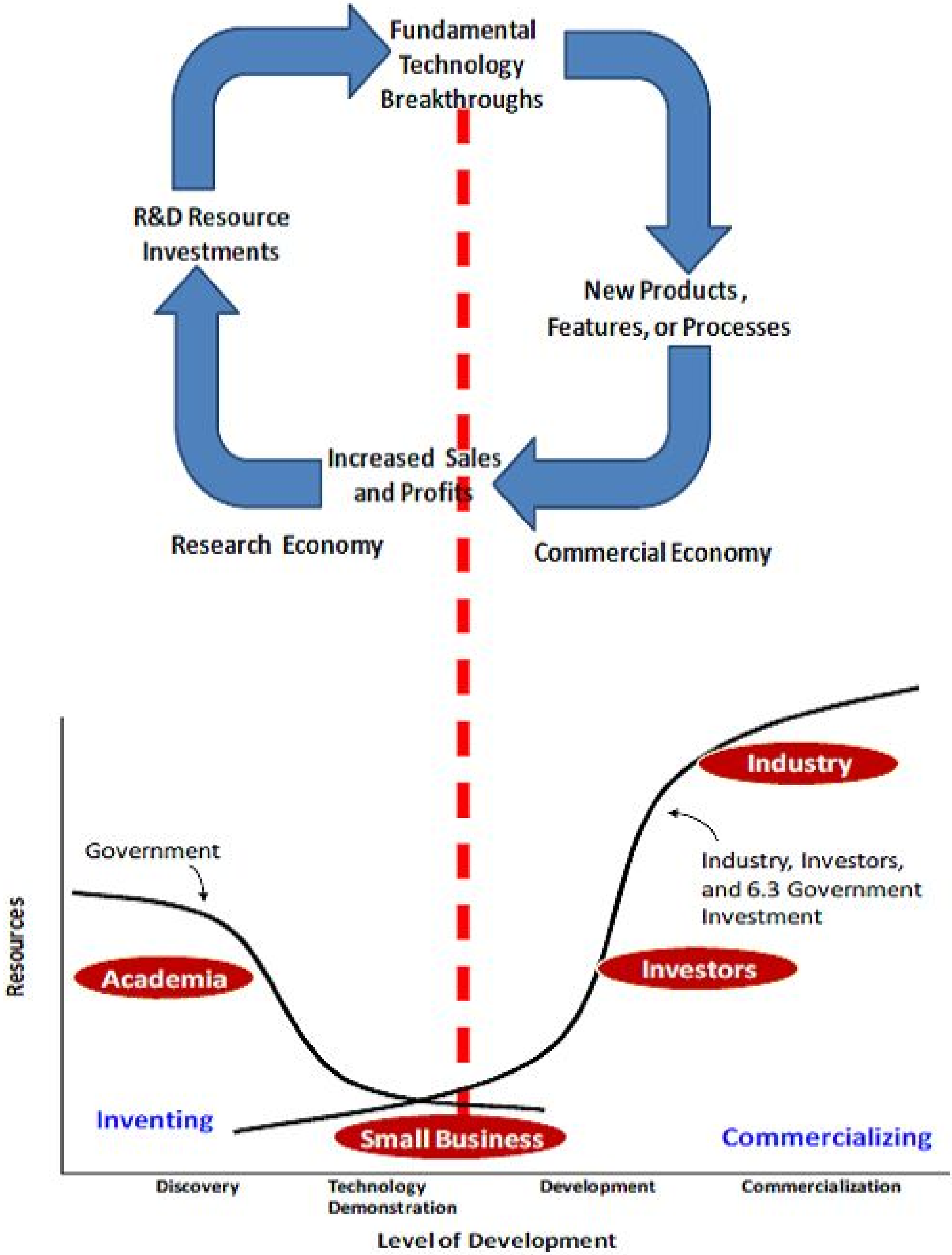

Figure 5-5â€"The â€œVirtuous Innovation Cycleâ€• Relationship to the Valley of Death

5.3.2 Intellectual Property Management and Delivery

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 administrations concerning ownership rights to intellectual property. 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 a central purpose of the ERC.

Intellectual property rights specified in the membership agreement are influenced by the type of industry, by the university's experience, and by common sense. The type of membership structure also should influence IP decisions. If all of the center's core research activity is precompetitive and supported in common, shared rights for all members may be appropriate. If the center has, in addition to core 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 5.3.2.

Sections 5.1.1 have already discussed the need for pre-establishing agreements among the ERC, host university, partner universities, industry members, and ERC researchers to assure that systems and protocols are in place to get the ERC successfully launched. As discussed in those sections, Intellectual Property management clauses and terms is a key component of those agreements and so will not be repeated here.

5.3.2.1 The ERC IP Process Flow

However, it is instructive to discuss Intellectual Property Management protocol in a more granular fashionâ€"that is, from invention disclosure to ultimate licensing. It is anticipated that development leading to commercially viable products and processes will be primarily performed by industry members, rather than the ERC; but it is truly a partnership to develop and translate ERC research to market-impacting offerings. This section describes best practices in the steps of that process. Note that further detail can be found through examination of the Sample ERC Industrial Membership Agreement in Attachment 5-C. The basic ERC IP Flow Process is illustrated in Figure 5-6 and is discussed below.

When the figure is read from left to right, it illustrates the hierarchy of potential commercialization pathways, ranked from lowest to highest risk. The available options for innovation commercialization are (a) translation to industrial partners for further development, (b) licensing technology to a non-member firm for further development, and (c) licensing technology to a university-initiated start-up focused on translating the technology. NSF intends that the ERC will place the highest priority in developing industry relationships on cultivating IAB members and other firms that co-invest with NSF in the ERC enterprise. Small businesses in all three options are eligible to apply for funding from the NSF translational Small-Business/ERC Collaborative Opportunity (SECO) fund. Since NSF is not in the business of launching start-ups, nor does it have the resources to shepherd a start-up through to success, the start-up option should be used only as a last resort when no other options avail themselves.

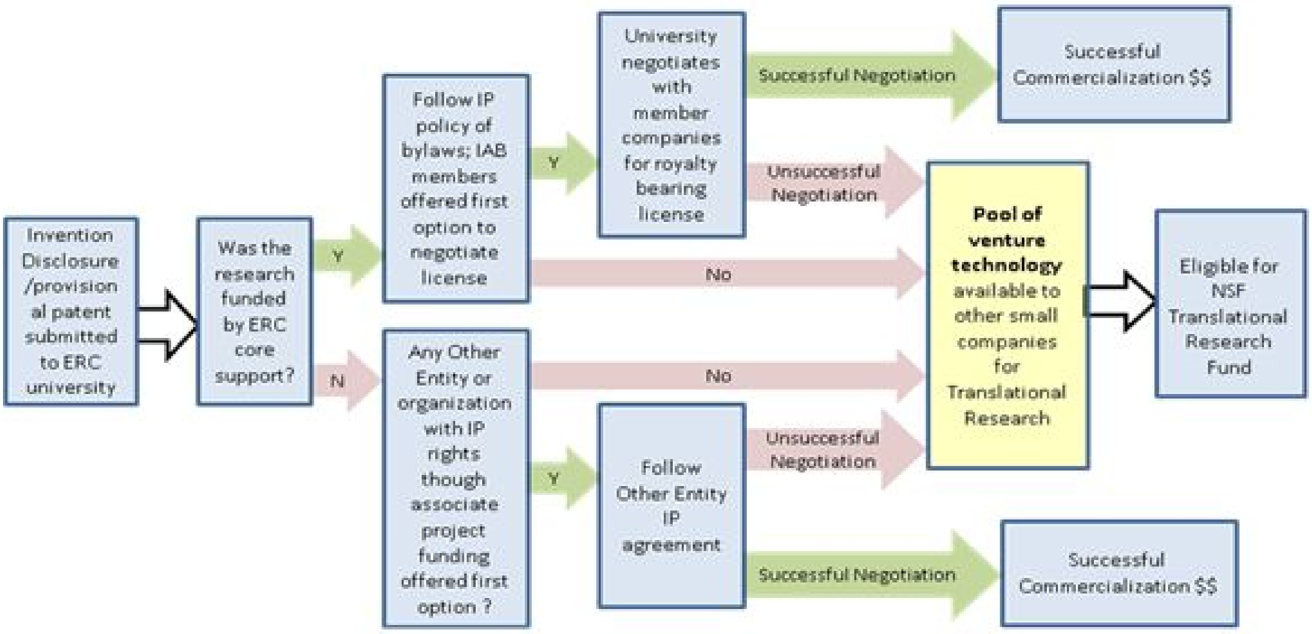

Figure 5-6: ERC Intellectual Property Flow Diagram

5.3.2.2 Membership Levels and IP Rights

Many ERCs have developed â€œtieredâ€• approaches to industrial 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 duesâ€"see, for example, the discussion of Section 5.1.2 and the Sample ERC Industrial Membership Agreement of Attachment 5-C. The advantages of this system are that the ERC obtains increased annual membership funding based on the expected future value of IP and 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.

5.3.2.3 IP in Relation to Funding Source

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

- *ERC Core Research* â€“ This is research that is funded through Center unrestricted, discretionary funds. As with most university intellectual property, IP generated from ERC core research is not normally subject to ownership by industry, although ERC industry members enjoy preferential licensing rights to this technology over non-associated companies. Industry members enjoy a first option on licensing, a non-exclusive royalty free (NERF) license or other benefits, compared with non-associated companies, for IP generated from ERC core research, per the ERC Industrial Membership Agreement.
- *ERC Sponsored / Directed Research* â€“ This category of research comprises projects usually funded by a single company through a separate research agreement that outlines terms and conditions specific to that

research project, and is managed through the ERC. IP resulting from research funded by a single company may be subject to IP rights by the sponsoring company, depending on the specific agreement between the university and the company. Some ERCs confer ownership of IP from sponsored research to the sponsoring industry member based on a premium level of membership. This is the first mode for translational research in ERCs.
- *Associated Research* â€“ Associated projects are also sponsored or directed research projects in the scientific/technical field of the ERC, but are funded through the home department of a center researcher rather than through the ERC. Associated projects are only included in the ERCâ€™s research project portfolio if all or part of the project is critical to the ERC achieving its strategic research plan. Many of the characteristics of the ERC sponsored research project apply here as well. It is important for ERCs and the NSF to capture and report the level of ERC Sponsored / Directed and Associated Research, as this captures the breadth of the impact of the ERC and its researchers in the field of focus of the ERC.
- *Research Funded by a Consortium of Companies* âˆ' IP ownership and licensing rights are further complicated by the involvement of several companies (usually a subset of industry 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 typical that all members of the consortium have equal access to the technology and equal rights for IP ownership or use through licensing, although this can be specific to the ERC and specific consortium needs.

5.3.2.4 Invention Disclosure to University and ERC

The ERC has a contractual obligation to its industry members to provide ERC Core Research invention disclosures in a timely manner so that members can get an early look at inventions and decide whether to exercise any IP rights (e.g., first option to negotiate a license or NERF license) provided through the Membership Agreement. The key is to establish a system between the ERC and the university (host and partners) to identify ERC inventions in a timely manner. ERCs have implemented systems such as:

- ERC researchers being instructed to submit ERC supported research inventions to both the university technology transfer office and the ERC ILO simultaneously;
- The ERC ILO communicating regularly (e.g., monthly) with their university technology transfer offices to assure that ERC funded research subject to Industrial Membership Agreement rights are identified timely;
- University technology transfer offices customizing their invention intake systems to flag the NSF ERC agreement number to identify ERC core research inventions; and
- ILOs communicating regularly (e.g., monthly) with ERC funded researchers to query if any invention disclosures have been submitted or are in preparation.

Each ERC will need to determine the system that works best for it with its lead and partner universities. The ERC also has to determine a time period within which the IAB members can review the IP and either exercise the right to license or decline. The time period should be long enough for a reasonable corporate review but short enough to facilitate other avenues for commercialization. If itâ€™s too short, it may imply to the IAB that the faculty are not interested in technology transfer to member firms but would rather spin-off the technology to their own firms. It should be again stressed that ERC-related IP must follow the flow of the IP Flow Diagram of Figure 5-6 assuring ERC members a first opportunity to license and commercialize ERC derived IP.

5.3.2.5 Intellectual Property Vetting

For non-ERC inventions, university technology transfer offices typically vet university researcher invention disclosures for commercial potential through the experience of members of the office, sometimes with guidance from outside subject matter experts or groups. 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 prosecution. Committees of this kind may include university administration, legal staff, and researchers. ERCs have the distinct advantage of having a consortium of companies interested in the field of research and so can add substantially to review of inventions for commercial potential.

Some ERCs have established an IP Protection Fund, usually taken from the partial proceeds of industrial membership fees of a higher level tier of membership. This provides the dual advantage of engaging industry members in IP vetting and providing funds for initial protection of IP (e.g., Provisional Patent Applications).

CASE STUDY: The FREEDM Systems ERC established an Intellectual Property Protection Fund (IPPF) as a resource to be used to secure protection associated with the most promising disclosures of Center Intellectual Property, defined as inventions created by Center Core research supported with NSF funds and Membersâ€™ fees. Annual contribution to IPPF is $5,000 per Full member, which comes out of the membership fees paid to NC State. Associate and Affiliate members do not contribute to the IPPF. Contributions to the IPPF are held separately from the membership pool funds. Unused portions of the IPPF may be reassigned periodically to provide support to Center research projects funded out of the membership pool. A teleconference is held where Industry Advisory Board members discuss and review invention disclosures and make recommendations on IPPF protection actions. The Center may reimburse the patenting cost using IPPF funds up to $10,000 per invention.

5.3.2.6 Invention Disclosure to Industry Members

The next step in the process is transmission of the invention to industry members, assuming that right is included in the Industrial Membership Agreement. Tiered membership structures will most often differentiate IP rights between tiers, so not all industry members may have rights to review Invention Disclosures, or abstracts thereof. For those that do, the Membership Agreement typically provides that the ERC will forward invention disclosures to industry members in a timely manner and provides members with a fixed time frame (usually 60-120 days from mailing of the invention disclosure) to indicate whether the company wishes to exercise any IP rights given in their Membership Agreement. The university will typically agree through the Membership Agreement to not engage in license discussions with non-members in the time frame allowed for industry member review.

Transmission of ERC Invention Disclosures to members is usually done through U.S. mail, but sometimes through email, and preferably through posting on the secure portion of the ERC website. Sending emails to industry members indicating that new invention disclosures are available for review through the ERCâ€™s secure website provides the advantages of being able to track members that access the information and also allows multiple groups that are authorized to access the information in a member company to easily review the invention disclosure.

However the invention disclosure is introduced to members, sometimes companies may not want to read the full invention disclosure (or even receive invention disclosures) in order to not compromise company intellectual property that may be under developmentâ€”commonly known as â€œcontaminationâ€• of company internal IP. The ERC can mitigate this concern:

- By providing only a non-enabling abstract of the invention to industry by regular mail or email and inviting them to request the full invention disclosure if they wish;
- If providing the invention disclosure by regular mail, enclose it in a sealed envelope with a non-enabling abstract external to the sealed envelope and a tear-off return slip indicating whether the industry member reviewed the full disclosure and whether it wishes to exercise any IP rights granted in the Membership Agreement; or
- If providing the invention disclosure by access to the ERCâ€™s secure website, assure that the member is directed first to a non-enabling disclosure on the site and then clicks through to the full invention disclosure if they wish, using a password or some other trackable form of access.

CASE STUDY: The BioMimetic Engineered Systems (BMES) ERC, based at the University of Southern California (USC) utilizes a unique approach with respect to its IP portfolio. Specifically, their universityâ€™s tech transfer office assumes all patent prosecution expenses without participation from the Center industry members. Center management takes a very proactive role in developing robust provisional patent applications with strong support from the Stevens Institute. This level of attention is attributed to the tremendous track record of past BMES start-ups, which is well known to USC administration. Director Dr. Mark Humayun estimates that some 80-85% of BMES patents are eventually licensed, which provides great credibility for future Stevens Institute patenting decisions. This level of support provides BMES with much greater freedom than most ERCs have in managing their IP portfolio. For instance, BMES typically only notifies industry partners when a patent is getting ready to issueâ€”much later than other ERCs, which notify industry partners upon invention disclosure. In some cases, BMES lists invention disclosures at the discretion of the faculty members.

5.3.2.7 Industry Member Rights

Typically, ERC inventions conceived or first reduced to practice by ERC researchers in the course of ERC Core Research have ownership (title) vested in the researcherâ€™s home university. If there are joint researchers from multiple universities, or researchers from one or more partner universities along with industry researchers (a less common case), IP ownership is typically jointly shared among all of the inventing partiesâ€"typically the universities or companies as designee of ownership through the researcher employee agreements.

Ownership rights are usually not transferred through the ERC Industrial Membership Agreement. Rather, license (commercialization) rights are usually provided to at least the top tier of industrial membership through the Membership Agreement as discussed below.

IP rights granted by each ERC to its industrial membership are specific to that ERC / university and the needs and standards of the target industry. The Sample Industrial Membership Agreement of Attachment 5-C provides a typical scenario, but this should be tailored to each ERCâ€™s specific situation.

Many ERCs grant industry members a right to a non-exclusive, royalty-free license for in-house (research only) use of inventions that come from ERC Core Research. This specifically excludes any commercial application of the technology and any companies that wish to exercise this right will typically share in patent application, processing, and maintenance costs. This scheme allows the industry member to explore development of products and services that might come from the core research, while providing the university with financial (license royalty) returns should the company wish to fully commercialize the technology. This strategy shares the risks and returns of development and commercialization of ERC Core Research.

If such NERFs are granted, or if other IP non-exclusive rights such as field-of-use license rights are granted through the Membership Agreement, the ERC / university must decide if exclusive license rights that may be granted to and exercised by industry members should take precedence. This is a decision for the ERC and university based on their vision for maximizing IP returns overall. In any case, industry members should be notified of any exercise of rights that may infringe on their rights (e.g,. exclusive IP rights over NERF rights), so that each company can make the best business decision for moving forward with exercise of their rights.

These licenses may provide for sublicense rights to industry member affiliates or subsidiaries, or even to third parties at the discretion of the ERC universities and may also include rights to derivative works (future developments) based on the subject IP. The agreement among the partnering university on these terms is captured in their Inter-institutional Agreement, discussed in Section 5.1.1.3.

Finally, the Industry Membership Agreement should always include a grant-back right for university researchers to continue development of the research for academic purposes.

5.3.2.8 License Negotiation

License negotiations are typically handled by the university as non-ERC university IP. One ERC-specific consideration is that with multi-university ERCs, the Inter-institutional Agreement discussed in Section 5.1.1.3 should include a clause assuring that one university takes responsibility for license negotiations so that the company is dealing with one entity, even where the inventors are from multiple universities.

5.3.2.9 Sponsored Projects with Member and Non-Member Large Firms

Industry recognizes that the value to be gained from ERC membership can take many forms, including early exposure to results from the ERC core research and the ability to engage with leading faculty and students in the field of interest to industry members. This can provide industry members with an advantageous position to engage in sponsored research projects with ERC faculty to further advance ERC research of specific interest to the industry member. While all industry members share in the ERC core research results per the ERC membership agreement, industry members also have an opportunity to gain a proprietary IP position in further research that is sponsored by an individual company. In this way, the industry member can take advantage of the knowledge provided by the ERC core research base, which is shared among all industry members, as well as developments from directed research, for which the company sponsor will have commercialization rights as determined by the specific sponsored research agreementâ€"usually a first option to negotiate a license for IP that is developed in the sponsored research project.

Companies that are not members have the opportunity to sponsor research with the university faculty, but will not have the advantage of having the early view of the advancements from the ERC core research provided by ERC membership.

In either case, sponsored projects provide an excellent opportunity to engage more deeply with industry members, engage with companies that are not yet members, and move ERC technology to industry for further development and commercialization. However, the ERC must assure that ERC core research is clearly delineated from sponsored research in application of industry member and sponsored project IP rights.

5.3.2.10 NSF Translational Research Fund

NSF recognizes that ERC research can result in technology that has commercial potential but is at an earlier stage than industry is ready to adopt through licensing. In some cases, ERC research results in inventions that have gone through the standard IP management process of Figure 5-6, do not result in licenses, and could be moved further in commercial potential through incremental funding. ERC-developed IP is qualified to compete for NSF Translational Research Funds only if it has been evaluated and reviewed following the centerâ€™s membership bylaws per the Center IP Flow Chart of Figure 5-6. A proposal is submitted by a small member or non-member firm to the SECO solicitation with a sub-award to the ERC faculty associated with the initial technology. In this way, because the research is separately supported by the ERC program and not by the ERC itself, any secondary IP emerging from the translational research project stays with the small firm awardee and does not revert to the IAB or the source university.

5.3.3 Engagement of Innovation Partners

Discussion of Innovation Partners here includes internal organizations such as university technology transfer groups and centers for entrepreneurship and innovation, as this is essentially an issue of leveraging complementary resources, whether internal or external to the university.

The ERC ILO should fully utilize university and appropriate external resources to meet the centerâ€™s industrial collaboration and innovation goals, but must remain mindful of each organizationâ€™s drivers or this activity can result in a force fit that produces little of meaningful value, as will be discussed here.

There is a strong need for ERCs to engage all of the university and external innovation partner resources in recruiting industrial partners and transitioning technology to the marketplace. Engaging with economic development groups, alumni affairs and development offices, etc., can be a foreign concept to most university-based research centers that are very much focused on basic research and that rely on the universityâ€™s standard intellectual property management protocol (e.g., invention disclosure submission, vetting for patenting, marketing for licensing or spinoff, technology licensing). ERCs are unique in a university with regard to their industrial interaction requirements to go a step beyond in their focus on innovation, and so require a special focus on leveraging resources from within and outside the university that can support their mission.

ERCs should regularly review whether they are engaging all the potential innovation and administrative partners in the process of identifying and recruiting new members to the IAB. This list would include:

- All technology transfer offices of the ERC Partner Universities;
- IAB Members;
- University Partner Business Schools, and especially centers focused on entrepreneurship and innovation;
- University and department development, alumni and corporate relations personnel;
- Innovation organizations in the region;
- Angel investors and venture funds; and
- Regional and State Economic Development Organizations.

These groups can be engaged to utilize their existing infrastructure and processes to vet university technology, and networks to broader segments. These groups will benefit by increasing their opportunity pipeline with high quality technological innovations that they can promote to their contacts, and therefore increase their value to their constituents. The ERC is a unique structure in a university that engages industry in basic to systems-level developments with an innovation focus, and this can be attractive to these partners.

For instance, economic development groups are usually looking for opportunities for industry to leverage university research to benefit company directions, and recruitment to the state or areaâ€”an opportunity specifically suited to ERCs with their focus on industry and innovation. University-based centers for entrepreneurship can increase their influence on campus by providing workshops and courses in entrepreneurship to faculty and students that can support the ERCâ€™s innovation program. Technology transfer offices many times produce technology showcases for entrepreneurs, investors, and companies that can be well served by inclusion of ERC research and advances. University Development Offices are always looking for great case studies of university research programs that can significantly impact quality of life for development of philanthropy targets, whether individuals or companies.

There many mutually beneficial opportunities to work with these groups and these should be leveraged, but only to the direct benefit of the ERC and partnering organization. Force fits in order to count Innovation Partners usually donâ€™t result in any significant benefit to either party and the ILO should constantly be on watch to assure that these groups are best utilized for front-end industry/entrepreneur recruitment to the industrial or innovation partners programs or on the back-end as technology commercialization outlets.

This feature is required of Gen-3 ERCs but is a means of strengthening the technology impact of Gen-2 ERCs as well.

CASE STUDY: ERCs can act as a venue for commercial vetting of a broader university research base, such as is done by the QoLT Foundry. Although the QoLT ERC is actually a Gen-2 ERC, it has implemented a vibrant innovation-to-commercialization program that is a front-runner among ERCs and could serve well as a Best Practice for Gen-3 ERCs. The QoLT Foundry is focused on identification, evaluation and commercial advancement of technologies from core ERC and associated research within Carnegie Mellon University (CMU) and the University of Pittsburgh. Established in 2008 with support from CMU, a local foundation, and an ERC Program Innovation grant, the Foundry has demonstrated remarkable success: 12 companies created since its inception and more on the way. Rather than waiting for researchers to form start-up companies, QoLT has taken the innovative approach to reduce the time-to-market for QoLT technologies by being proactive about identifying and cultivating opportunities to form start-ups. The Founder is led by experienced Entrepreneurs-in-Residence (EIRs) who serve as consultants on time-limited (6-9 months) contracts and are chartered to find their â€œnext new thingâ€• in the form of a spin-off company. Foundry internsâ€”CMU and Pitt students in business, law, and management programsâ€”work with the EIRs to conduct market analyses, assess intellectual property strength, scan competitors and develop business models. Those are presented to potential investors, industry advisors, and innovation partners (regional technology-based economic development organizations) in â€œOpportunity Meetingsâ€• organized twice a year. Because they are a proven success, Foundry elements have been adopted by new campus-wide CMU programs that have broader reach within the university.

5.3.4 Real and Perceived Conflict 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 Foundationâ€™s â€œEngineering Research Centers Program Statement on Conflict of Interest in Technology Transfer on the Dual Role of Center Faculty in an Industrial Capacityâ€•:

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 companiesâ€”financial or otherwiseâ€”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, â€œInvestigator Financial Disclosure Policy,â€• of the General Conditions, which incorporates by reference Section 510 of NSFâ€™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 Leadership Team, or Thrust Area Leaders). 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.

Conflict of interest (COI) and particularly financial conflict of interest (FCOI) can be a looming challenge in ERCs, and especially so as ERCs drive toward an increased focus on innovation. (See the material on COI at http://erc-assoc.org/ilo-forum). The NSF encourages ERCs to work closely with start-up firms to carry out translational research, promote entrepreneurship, and impact economic development. As such and appropriately so, several ERC faculty members, including in some cases the director, have been tightly coupled with start-up companies, either as founders, officers, advisors, or consultants. Large companies can be reluctant to join or heavily contribute to an ERC that has a focus on innovation if they see this as a pipelining of technology to small companies, or even potential ERC spin-off companies. There can be an inherent COI challenge for faculty or ERC leadership that start up companies or are involved in spin-offs if those companies compete for ERC technologies with industry members. Project funding decisions that are being driven to a great degree by, or at least heavily influenced by, ERC leadership who have a personal stake in the outcomes of those decisions through start-ups, might be perceived as compromised, and this could be extended to the ERC. The university COI policy is typically not set up to address this situation (companies being reluctant to join if they see innovation programs as stymieing their ability to access technology), as the university COI policies are typically focused on managing the back endâ€”post invention and into licensing. While each partner university typically has a conflict of interest policy and management plan, a process to identify and manage COI at the ERC level (across all institutions and partners) has sometimes not existed, but should be established early.

5.3.5 Education Programs with Industry

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. (See Chapter 4 of the Best Practices Manual for a more extensive discussion of industrial involvement in ERC education programs.)

The Gen-3 ERC innovation strategy has a large component of student (and faculty) training in innovation and entrepreneurship as well as a focus on bringing in industrial and innovation partners to provide workshops, experiential education opportunities, technology assessments, internships, etc. As such, the ERCs have a three-fold education mission:

- Develop ERC graduates who will be more effective in industry and more creative and innovative leaders in a global economy;
- Integrate the ERCâ€™s research into the undergraduate and graduate curricula; and
- Develop partnerships with pre-college institutions, engaging teachers in engineering research to bring engineering concepts to the pre-college classrooms in order to attract students to careers in engineering.

For this education mission to be effective, the ERC ILOs and Directors for Education need to partner to nurture the culture of the innovation ecosystem. The Center Director should insure that there is seamless coordination between the ILO and the Education Director to avoid the development of conflicting education and innovation ecosystem agendas.

One challenge to ERCs is to capture the excitement and interaction of the industrial partner meetings/retreats at other times. Students and industry can come out of semi-annual meetings energized from their one-on-one interactions, but this excitement quickly fades as each party goes back to their everyday activities. The key is to find ways to increase the frequency of interactions, which can occur in everything from ERC-wide events to individual project industry guidance. ERCs should explore creating avenues for students to meet with industry, such as by sponsoring a reception at appropriate society meetings or other natural gatherings. ERCs might also explore unique means for students to present their research projects and industry to provide feedback in an exciting environment such as a reception with â€œ2 Minuteâ€“2 Slideâ€• presentations (essentially student Elevator Pitches of their research projects), with industry providing real-time feedback.

CASE STUDY: Beginning in 2011, the ERC Program has sponsored a Program-wide â€œPerfect Pitchâ€• competition that begins at the center level and culminates in a competition among center winners at the ERC Program Meeting. This competition focuses on the ability of ERC students to explain their research and its importance clearly and succinctly to a broad audience. The competition is judged at the meeting by a panel of industrialists, entrepreneurial faculty, and venture capitalists. The winning student is awarded a substantial cash prize and the studentâ€™s home institution takes custody of the Lynn Preston Perfect Pitch trophy until the next competition. Cash prizes are also awarded to second- and third-place students.

CASE STUDY: Student Leadership Councils can design creative ways to engage industry. For example, the Center for Integrated Access Networks (CIAN) hosts a speed-introduction event with one-page project summary slides in a quad-chart format (summary, schedule, deliverables/impact, and graphic). Additionally, the Student Leadership Councilâ€™s Student ILO coordinates monthly Industry web presentations. However, SLCs need ERC leadership support in terms of direction and guidance, funding, contacts, and organization in order to gain maximum benefit from such activities.

CASE STUDY: C-SOPS organizes â€œLunch and Learnâ€• seminars to bring in industry speakers and expose faculty and students to industrial practice. They have also hosted lectures and workshops that have industry speakers or panelists. There is strong participation in an industry mentorship program and great involvement of industry mentors on center projects providing exposure to industry practices through research teams. C-SOPS has designed a well-integrated set of programs that connected undergraduate and graduate education, curriculum development, continuous education for industry members, and programs to enhance public awareness. Of particular interest is the PharmaHub web site (http://pharmahub.org/) that is being used as a â€œknowledge repositoryâ€• to make presentations and modules openly available. Presentations and teaching materials can be downloaded, along with numerous tools and resources listed.

CASE STUDY: Recognizing the challenge of getting from discovery to proof-of-concept (the "Valley of Death"), the ERC for Biorenewable Chemicals (CBiRC) is meeting that challenge (which it terms the â€œDitch of Despairâ€•) with a technology-led entrepreneurship program that builds awareness of faculty and students regarding the various issues. At the core of CBiRC's approach is a course covering the steps in creating a startup. This Entrepreneurship Course builds understanding of what it takes to develop a technology-led idea into an early-stage entrepreneurial business proposition. Topics include (i) discovery research and how technology relates to innovation and the potential for entrepreneurship; (ii) critical techno-commercial analysis, intellectual property, and how to evaluate risk and reward; (iii) how to define key assets in the context of generating a Business Model Canvas; (iv) working through the elements of a business proposition; and (v) the process of founding a company and securing early-stage funding. In addition, Entrepreneurship Mentoring helps startups by providing a process for evaluating the business opportunity within the context of the Business Model Canvas, which formulates good understanding of a future customerâ€™s needs in relation to the technology being developed and what it takes to meet these needs. This Entrepreneurship Program is broadly managed within CBiRCâ€™s â€œBiobased Foundry.â€• The program was started and is led by CBiRC's Innovation and Industry Collaboration Director, Dr. Peter Keeling.

5.3.6 Role of Venture Capitalists and Other Investors

Going back to the early days of the ERC program, some ERCs (e.g., University of Florida ERC for Particle Science and Technology, Georgia Tech/Emory Center for the Engineering of Living Tissues) were approached by venture capitalists to join the Industrial Membership Program. The venture capital interest was to gain an early look at the commercialization potential of ERC technology and engage with researchers who could help to locate new advances in a field and serve as subject matter experts to help in due diligence of company technologies under consideration by the venture capital firms. ERCs have traditionally avoided formal engagements with investors, primarily due to concerns that individual investors will come in, add little value to the research and education missions of the ERC, and simply abscond with the technologies. However, inclusion of the investment community can be a strong positive for an ERC if managed properly. The MIRTHE Investment Focus Group is an example.

CASE STUDY: MIRTHE established an Investment Focus Group (IFG) with full IAB endorsement. Venture capitalists, corporate, and angel investors have joined the IFG. The IFG objectives are to: a) educate the investment community on the promise and potential of mid-infrared technologies; b) provide mentorship for students and important networking opportunities for faculty, students, industry/practitioners to interact and leverage the knowledge and expertise of seasoned technology investors; c) establish pathways to speed innovation and accelerate commercialization opportunities; and d) assess technology readiness and determine potential approaches to commercialization. In summary, the IFG is configured to add value to MIRTHEâ€™s research, education, industry/practitioner, and innovation programs.

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[1] Jackson, Deborah J. (2012). What Is an Innovation Ecosystem? National Science Foundation, Arlington, VA. (http://erc-assoc.org/sites/default/files/download-files/DJackson_What-is-an-Innovation-Ecosystem.pdf)

[2] Jackson, Deborah J. (2012). What Is an Innovation Ecosystem? National Science Foundation, Arlington, VA. (http://erc-assoc.org/sites/default/files/download-files/DJackson_What-is-an-Innovation-Ecosystem.pdf)

5.4 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) or Innovation Ecosystem Director, who is responsible for establishing and maintaining a liaison between the ERC and its industrial sponsors, innovation facilitators, and faculty. Each center needs to decide during the start-up and development phase how they are going to carry out this function; guidance is provided in this section as to the key requirements, challenges, opportunities and benefits to the ERC and industry of this position.

5.4.1 Requirements and Functions of the ILO Position

Clarity as to what is expected of industrial collaboration and innovation programs in terms of outcomes (number of members, total membership fees, mix of small and large companies, companies representing different parts of the industry value chain, inventions, patents, licenses to large or small companies, spin-offs, small companies involved in translational research and technology commercialization, Innovation Facilitators involved in stimulating entrepreneurship and innovation, number of students trained in entrepreneurship and innovation, etc.) is critical to the success of the ERC industrial collaboration and innovation programs. While it is almost impossibleâ€”and probably not wiseâ€”to prescribe one set of metrics that fit ERCs across technology clusters, which involve myriad industry cultures (e.g., emerging biotech vs. established materials and manufacturing industries), ERCs must be clear on expected metrics as the ILOs are typically stretched in terms of time and attention. For instance, ILOs can choose to focus their attention on recruiting large vs. small companies into the Industrial Membership Program, and licensing offices can choose to target technology licensing to larger companies vs. spinning off companies in transitioning research to the marketplace.

A primary consideration is what role the Industrial Liaison Officer will play in the center. Marketing of the center, as discussed in Section 5.2.2, is the responsibility of everyone in the center. With that said, 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 skillset needed to perform the ERC ILO function is succinctly summarized as follows:

1. Ability to work with the Center Director in developing/implementing a Technology Transfer Strategic plan for the Center;
2. Ability to work closely with the Center Leadership Team to recruit new industry partners by networking and actively seeking opportunities for industrial participation in research as well as educational center activities;
3. Ability to retain and increase interaction with current center industry partners.
4. Ability to facilitate student/industry relations through internships, student participation in joint projects with industry, fellowships, seminars, career placement, etc.;
5. Ability to assist in the formation of new industry partnerships, start-ups, and other industrial enterprises;
6. Ability to work with the Tech Transfer Offices at the core universities in filing disclosures, technology transfer and licensing agreements;
7. Ability to develop invention handling procedures and participate in licensing negotiations in conjunction with industry partners and ERC core partner campus Technology Transfer offices;
8. Ability to organize periodic meetings with center industry partners;
9. Ability to maintain an active website for industry partners;
10. Ability to document financial contributions from center industry partners; and
11. Ability to prepare a report of industry collaborations for NSF.

The traditional ILO position is probably mis-titled, as liaising with industry only partly describes this professionalâ€™s responsibilities. Different titles that more accurately capture the responsibilities of the position have been discussed within the ILO community and in some cases applied, and this should be decided by the Director of each ERC. Many who occupy this position in Gen-3 ERCs are titled Innovation Ecosystem Director, Industry/Innovation Director, or Industrial Collaboration and Innovation Director.

The Industrial Liaison Officer is not always a single individual. In a number of cases, the ERCâ€™s ILO has teamed with previous ILOs or other professionals inside or outside of the ERC to undertake the responsibilities of industrial collaboration and innovation. In some cases, previous ILOs or those temporarily taking that role operate in broader economic development-focused organizations and this provides a great way to increase the centerâ€™s exposure.

One concern voiced by several ILOs 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 ILOs 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.

Itâ€™s important to establish the ILO position as an integral part of the center management team during the formation of the center. 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 and Innovation Partners. It is these relationships with industry and innovation catalysts that will become important to the center as it approaches self-sufficiency.

5.4.2 Critical Qualifications, Experiences, and Characteristics of a Successful ILO

ERC ILOs have always been well served by having an industrial background in their ERCâ€™s target industry because it is critical that the ILO have a working understanding of the research program, industry technology and talent needs, and industry landscape (major players, new entrants into the market, trends, regulatory environment, etc.). ERC program history has shown that an engineering or scientific educational background pertinent to the ERCâ€™s technology is certainly highly advantageous, if not requisite, to the foundation of a well-prepared ERC. Additionally, the ability to converse with the spectrum of researchers to senior administration in companies and the university has proven to be critical to successful ILOs, as industry decisions to collaborate with an ERC/university is typically driven by a combination of exciting research and a strong and demonstrable fit to business unit needs and future products or services. Additionally, a working knowledge of intellectual property agreements and processes (e.g., patent, copyright, trademark, service mark, trade secret, confidentiality agreements, sponsored research agreements, material transfer agreements, technology licenses, etc.) has served ILOs well as they are sometimes called upon to act as a broker between the university, ERC, and industry (including multinational corporations, small and medium-sized enterprises, and entrepreneurs or startup companies) in these areas. With the Gen-3 ERC focus on innovation, ILOs now require at least a fundamental understanding of the technology entrepreneur and investor world to better guide technologies through the â€œValley of Deathâ€• to commercialization through small entities, startup companies, and investor-driven initiatives.

5.4.3 Most Satisfying Aspects of the Role

Just as they define their job responsibilities differently, various ILOs also define job satisfaction in different ways, to some degree as a function of their specific job structures within particular centers.

Generally, ILOs enjoy the excitement and intellectual stimulation of working at the intersection of cutting-edge research and technology development; developing education experiences to produce a new type of high-value industry professional; working closely with ERC leadership, faculty, and industry partners in designing research programs to meet industry needs; and creating an environment that fosters innovation. While there are many challenges to the ILO position, as discussed in Section 5.4.4, the ILO position presents a rare opportunity to work in a creative environment of university/industry/government collaboration.

The constant challenge in building an industrial partnership base and maintaining the relationships with industry to serve the center, industry, and nation can be especially satisfying as the ILO sees the fruit of that labor with every research collaboration and knowledge and technology transferred to the private sector to impact the US economy and our citizensâ€™ quality of life.

Additionally, the ILO has the opportunity to work with Education and Outreach Director(s) in crafting education programs that provide ERC studentsâ€”and facultyâ€”with an understanding of industrial research and development practice, technology commercialization, and innovation. The ERC provides a unique structure that enables industry, the NSF, and universities to collaborate deeply and broadly.

Last but certainly not least, the ILO position provides for a unique experience that serves ERC ILOs well as they move to other positions in their careers. The ERC ILO is a high-profile national position and ILOs are typically known to many industry and university professionals as they promote the ERC.

5.4.4 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 ILO. Lack of support staff is a serious drawback for many. Most ILOs 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 donâ€™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;
- 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;
- 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; and
- 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 ILO 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 centerâ€™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 ILOâ€™s role often involves issues regarding intellectual property. 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 ILOâ€™s responsibilities.

5.5 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.

5.5.1 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 centerâ€™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 a cross-disciplinary 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 â€œgraduatedâ€• ERCs. The great majority (over 80%) find that they do maintain reasonable industrial support from the established membership, based on their track record and reputation, although in many cases the nature of the relationship changes, as does the configuration of the membership.

5.5.2 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 meeting (now held every other year, usually in late November);
- NSF-sponsored ILO retreats organized by the ILOs to focus on topical issues of importance to active ERCs;
- Monthly ILO Working Group web conferences organized by NSF to disseminate information of use to the ILOs and gain feedback from the ILOs regarding program policies and operational procedures; and
- ILO consultancy visits to train new ILOs (generally in the first 18 months after a new ERC is established).

The biennial Program 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 and ERCs with new ILOs to provide personalized guidance and insight into establishing more effective industry collaboration and technology transfer.

5.5.3 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 members. The following suggestions are provided as ways to build a trusted partnership between NSF, industry, and the ERC:

- Invite the PD to industry meetings, perhaps via electronic means, to communicate the NSF ERC culture and philosophies;
- Encourage industry to communicate directly with the PD if there are pressing issues, both positive and negative; and
- 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 provide a few remarks at the beginning and then leave, or to remain as an observer or facilitator.

5.5.4 NSF as Evangelist and Shepherd

The ERC 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 and innovation partners, ultimately to attain a state of financial self-sufficiency (that is, independence from NSF 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 basisâ€”not as part of centers with strategically integrated research and education programsâ€”and often only for defined periods and projects, not on an ongoing basis.

The ERC paradigm 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 and innovation partnerships, some faculty in the departments and even in the center may be resistant to aspects of the program. Such resistance can be burdensome to a Center Director and the other members of the leadership team. Even among those not directly resistant, time is required to change their outlooks and get them to subscribe to the ERC concept. Over time, however, the ERCs have had a cumulative impact on academic engineering in the US that has softened this resistanceâ€”part of the â€œculture changeâ€• envisioned in the original founding of the Program.

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 centerâ€™s progress is crucial to this role, as is the firm but gentle use of the shepherdâ€™s staff.

5.6 Overall Summary

The perspective of the ERCâ€™s Industrial Liaison Officer is a bipolar one, which involves championing industryâ€™s views to academics as well as representing the university center and culture 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 itâ€”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 centerâ€”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 investmentâ€”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 chance to incorporate it in their operations.
- Industry must have a strong role in setting the centerâ€™s research agenda.

In recruiting members, especially for a new 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, education, outreach, and innovation;
- Cooperative research projects and personnel exchanges;
- Student internships in industry;
- Using senior-level students as links to industry;
- Workshops;
- Keeping a current contacts tracking database; and
- Developing solid metrics for assessing the industrial interaction.

NSF, and in particular the Leader of the ERC Program and the individual ERCâ€™s 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.

Attachment 5-A - ERCs and Abbreviations as of October 2019

Advanced Manufacturing

- Center for Biorenewable Chemicals (CBiRC)
- Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT)

Biotechnology and Health Care

- Nanosystems ERC for Cellular Metamaterials (CELL-MET)
- ERC for Cell Manufacturing Technologies (CMaT)
- ERC for Revolutionizing Metallic Biomaterials (RMB)
- Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)
- ERC for Precise Advanced Technologies and Health Systems for Underserved Populations (PATHS-UP)
- Center for Neurotechnology (CNT)

Energy, Sustainability, and Infrastructure

- ERC for Quantum Energy and Sustainable Solar Technologies (QESST)
- ERC for Bio-mediated and Bio-inspired Geotechnics (CBBG)
- Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center
- Nanosystems ERC for Nanotechnology Enabled Water Treatment Systems (NEWT)
- ERC for Re-Inventing AmericaÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢s Urban Water Infrastructure (ReNUWIt)
- ERC for Ultra-wide Area Resilient Electric Energy Transmission Networks (CURENT)
-

ERC for Innovative and Strategic Transformation of Alkane Resources (CISTAR)

Microelectronics, Sensing, and Information Technology

- Center for Integrated Access Networks (CIAN)
- Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems (TANMS)
- ERC for Power Optimization for Electro-Thermal Systems (POETS)
- ERC for Lighting Enabled Systems & Applications (LESA)

Attachment 5-B - NSF's Cooperative Agreement Program Terms and Conditions on Industrial Collaboration in ERCs

1. The ERC's industrial/practitioner partnership program will be governed by an ERC-wide membership agreement, including a uniform IP policy for ERC-generated IP at the lead and each of the ERC's partner universities. The membership agreement defines the scope and function of the ERC's partnership with industry/practitioner organizations, the types of membership such as full, affiliate, contributing, etc, the respective membership fees, and the ERC's Intellectual Property (IP) policy. The ERC has developed an IP policy that facilitates the roles of industrial partners in Gen-3 ERCs and is flexible in recognizing IP jointly developed by faculty in different universities or that developed by joint industry and university research.
2. Foreign firms may be members of the ERC as long as they participate in accordance with the same membership agreement as U.S. firms do. Domestic and foreign member firms/practitioner organizations will contribute financially to the ERC and will have first rights of refusal for ERC-generated Intellectual property (IP), according to the terms of the agreement.
3. The ERC will function with an Industrial Advisory Board (IAB) involving all of its Industry/practitioner members. The IAB will meet at least twice a year, carry out an annual analysis of the ERC's strengths, weaknesses, opportunities and threats to survival (a SWOT analysis), and participate in the annual NSF review of the ERC's performance and plans. During the meeting with the NSF site visit team, the Chair of the IAB will present the IAB's SWOT analysis to the review team and discuss the findings. The SWOT will be updated annually and progress of the ERC in addressing the SWOT will be discussed with the NSF site visit team as well. The Chair and the IAB members also will discuss the annual SWOT analysis with the ERC Director and the ERC Leadership team to determine appropriate future strategies to deal with the weaknesses and threats.
4. Industrial consortia may join the ERC, but benefits of membership do not accrue to firms that are consortia members, unless they are also paying membership fees to the ERC as members separate from the consortia
5. Throughout the course of the ERC's funding by NSF, the Center shall continue to develop and refine its technology transfer and innovation strategy and its Intellectual Property policy, the latter in accordance with NSF's Intellectual Property guidelines (NSF Award and Administration Guide, Chapter VI.D., "Intellectual Property") and the Awardee's policies.
6. Industrial membership fees are treated as Program Income, and must be allocated for use for Center purposes. Industrial membership fees that are not expended in the year in which they are received 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 included in the Center's annual report and reported to IAB during the IAB meetings. Industrial members may provide additional support for activities such as sponsored research projects, equipment donations, intellectual property donations, or educational grants.
7. Costs for organizing meetings with industry members will be borne by the ERC or the participants through a registration fee, as deemed appropriate. Costs for attending these meetings by industry members will be borne by their organizations.
8. All ERCs will have member firms engaged in translational research through sponsored projects, and small firms carrying out translational research supported by funds from the ERC Program's Translational Research Fund or other non-ERC, non-university sources for ERC-generated Intellectual Property (IP) that member firms do not license.
9. In addition, as a Gen-3 ERC, the ERC will develop and nurture the innovation ecosystem for the purposes

of accelerating the translation of knowledge into innovation, by:

i. Stimulating member firms to support sponsored projects for the purposes of translating ERC-generated IP to commercialization;
ii. Forming collaborations with small firms for the purpose of translating ERC-generated IP to the marketplace, if member firms do not license the IP—(This should be done via licensing IP, knowledge transfer to the firm, and/or securing translational research funds to accelerate commercialization of the technology by the small business in partnership with the ERC. Translational research funds could be secured from the ERC Translational Research Fund and/or from funding from other non-ERC/non-university sources);
iii. Building partnerships with federal, state, or local government programs designed to develop entrepreneurs, support start-up firms, and otherwise speed the translation of ERC-generated knowledge and technology into practice and products; and
iv. Leveraging technology commercialization opportunities offered by the federal Small Business Innovation Research (SBIR)/Small Business Technology Transfer Research (STTR) programs. The ERC will include analyses to determine the most effective methodologies to use to achieve these innovation goals through these types of partnerships.
v. In reference to 9(ii) above, ERCs will classify their IP generated from research under the scope of the ERC's strategic plan as core IP (IP resulting from center-controlled unrestricted funds) and Project IP (IP resulting from restricted funds that flow through the center or flow directly to a PI). For Core IP and Project IP, the member firms / practitioner organizations or the sponsoring firm/practitioner organization, respectively, will be offered the first option to negotiate a license. If there is no license forthcoming in either case, the IP can be offered to a small firm and a partnership formed between that firm and ERC faculty to carry out translational research to accelerate product development. Support for a translational research project to accelerate product development can be sought from NSF through the ERC Translational Research Fund; in that case, the small firm would be the submitting organization, with a subaward to the ERC faculty. In addition, in that case, the university must screen the project for ERC faculty, Industrial Liaison Officers (ILO) and/or ERC Executive Management personnel conflicts of interest. When conflicts are disclosed for any of the above three categories of personnel, the university impacted must develop a conflict management plan for each disclosure.
vi. In the case of a conflict, there will be a conflict of interest management plan. Progress and impacts of the project would be reported in the ERC's annual report. Because NSF would support such a project as an associated project outside the center's core funds, any additional IP developed from that project would not revert to the university or member firms.

Attachment 5-C - ERC Sample Industrial Membership Agreement

SAMPLE INDUSTRIAL PARTNER AGREEMENT[1]

UNIVERSITY NAME

ERC NAME

This Industrial Partner Agreement (hereinafter called Agreement) is made on this ____ day of ________________, by and between XXX (hereinafter called UNIVERSITY), and __________________ (hereinafter called MEMBER).

WHEREAS, the parties to this Agreement intend to join together in a cooperative effort to support ERC FULL NAME (hereinafter called ERC) at UNIVERSITY to establish a mechanism whereby the educational and research environment can be used to develop better understanding of GENERAL FIELD OF RESEARCH and stimulate industrial innovation.

AND WHEREAS, this program will strengthen ERC's and MEMBER's, technological and service capabilities.

NOW, THEREFORE, for the mutual premises and covenants contained herein, the parties hereto agree as follows:

1. UNIVERSITY agrees that the personnel and facilities required for the ERC will be available for research, education and service as needed to fulfill the purpose of this Agreement. ERC shall be operated by UNIVERSITY under the leadership of a Director. ERC will be supported jointly by various private and public sponsoring organizations, including MEMBERS, the National Science Foundation (hereinafter called NSF), UNIVERSITY, and the State of XXX.
2. UNIVERSITY, on behalf of ERC, will put into place agreements with XXX, XXX, and XXX (hereinafter called ERC PARTNERING UNIVERSITIES and collectively with UNIVERSITY called ERC UNIVERSITIES) to assure that the rights and obligations of MEMBER that apply to UNIVERSITY, will also apply to ERC PARTNERING UNIVERSITIES.
3. ERC's Industrial Partners Program (hereinafter called IPP) has been created to establish partnerships with companies or other entities which may promote ERC's mission. IPP participants are expected to play an important role in the research, education, technology transfer, and innovation goals of ERC including creating and demonstrating the scientific and technological feasibility of innovative methodologies and systems governing FIELD OF RESEARCH, assisting in the transfer of research discoveries and observations from university to industry and vice versa, and developing an interdisciplinary education program.

Any corporation, company, partnership, sole proprietorship, or any other legally recognized business entity, or any agency of government, government office, or government organization duly authorized by the United States Government or government of any State or Nation may become a MEMBER of the IPP.

The rights and obligations of MEMBER under this Agreement shall extend only to MEMBER's affiliates or subsidiaries who routinely share in a free flow of MEMBER's internal technical information.

4. The fee for participating in the Industrial Partners Program comprises a cash contribution as defined below. In addition, appropriate interactions with ERC administration and researchers to help ERC accomplish its mission are required. The interaction with ERC may include visits to the Center by the partner representatives, visits to the partner by faculty and students, and discussions at professional society meetings or conferences. IPP MEMBERS, during visits to ERC, can work on a mutually agreed upon research projects, mentor students, learn specialized techniques, and give special seminars. It is expected that during the course of their stay, they will develop strong interactions with ERC researchers. Required member duties include:

    a. Meeting a minimum of twice a year
    b. Developing an annual SWOT analysis and presenting to the NSF site visit team;
    c. Reviewing progress on ERC projects;
    d. Provide input on ERC strategic plans;
    e. Provide feedback on proposed project plans;
5. MEMBERS of the IPP are entitled to the following benefits:

- MEMBERS will receive a non-exclusive, royalty free grant of rights to all intellectual property developed by the ERC subject to the provisions defined below in this Agreement.
- MEMBERS may serve as elected representatives on the Technical Executive Committee (TEC). The TEC will be constituted so as to represent the broad spectrum of membership and will ensure the overall synergy of the research carried out in various thrust areas, and recommend to the ERC Director any mid-course corrections in research and/or personnel, as necessary. The TEC will be elected by voting members of the Industrial Advisory Board (IAB). The IAB will consist of all MEMBERS who shall have voting privileges. IAB MEMBERS will participate in recommending priorities of educational and research programs to the Center Director and in evaluation of progress towards the ERC's goals and objectives.
- MEMBERS will have rights to receive a discounted overhead rate of 25% UNIVERSITY Modified Total Director Cost (MTDC), reduced from UNIVERSITY standard 45% MTDC overhead rate, applied to any additional FIELD OF RESEARCH related research associated with ERC researchers which MEMBER sponsors. This favorable rate applies to contracts entered into with UNIVERSITY during MEMBER's participation in the IPP and requires full payment for the additional research in advance.
- MEMBERS will have priority access over non-partners of ERC to ERC facilities and instrumentation in the ERC at nominal fees to cover the operating costs.
- MEMBERS may request on-location short courses to be provided by ERC at fees to be negotiated between ERC and MEMBER to cover costs.

- MEMBERS will have access to the ERC Secure Web Site, which comprises an electronic information network maintained by the Center for timely exchange of information and facilitates access to the ERC created knowledge base of research advances. MEMBERS will have access to all ERC reports, publications, and invention disclosures, per the conditions in this agreement, through the ERC Secure Web Site.

6. Upon execution of this Agreement, payment shall be made as indicated below:

The annual fee for a MEMBER is based upon the number of full time employees within the MEMBER's corporate entity as defined in Section 3, Paragraph 3:

Number of Employees	Annual Fee
Less than 100	$XX
Between 100 and 500	$XX
More than 500	$XX

Payments shall be made annually, with the first payment being due within thirty (30) days of the execution of the Agreement. The initial term of the membership will be from execution of the Agreement through the following 12 months with subsequent terms continuing for 12 months thereafter.

Checks shall be made payable to: XX

Checks shall be mailed to: XX

7. All educational, research and other programs and administrative activity of ERC will be conducted with pooled resources with contributions from MEMBERS, and other sources, including NSF, as long as expenditures from these pools are deemed appropriate for the establishment and operation of the ERC.
8. This Agreement will be renewed annually with no action required of either party hereto. Either party of this Agreement may terminate annual continuation of the Agreement by providing the other party with written notice at least three months prior to the anniversary date of this Agreement. All notices shall be in writing and addressed to MEMBER's stated address or as follows:

UNIVERSITY ADDRESS

9. The organization and operation of the ERC shall be in accordance with existing procedures established by UNIVERSITY and all applicable State and Federal laws.
10. Intellectual Property and Publication Policies - It is anticipated that development leading to commercially viable products/processes will generally be performed by industrial partners rather than the ERC. If new technology is developed through ERC research, the following policies shall apply:

Invention Disclosure to ERC UNIVERSITIES and MEMBERS – UNIVERSITY researchers supported by ERC core funds are required to submit invention disclosures and/or copyrightable materials disclosures (Federal copyright registrations) to ERC UNIVERSITIES and ERC in a timely fashion. When ERC receives an invention disclosure and/or copyrightable materials disclosure, a copy will be provided to MEMBERS for their review, through either direct mail or the ERC Secure Web Site. UNIVERSITY agrees to a delay in licensing to non-partner companies for a period of 90 days following the disclosure of patentable inventions or copyrightable materials to MEMBERS.

Rights of MEMBER for Non-Exclusive, Royalty Free License for In-House Use of Inventions - All patentable inventions and copyrightable materials conceived or first actually reduced to practice by ERC supported researchers in the course of research conducted at the ERC shall have title vested in the researcher's home university. MEMBERS shall have a right to a non-exclusive, royalty-free license for in-house use of patentable inventions or copyrightable materials developed under the auspices of the ERC. For clarity, in-house use is limited to in-house research and development purposes only and specifically excludes commercial application(s) of the subject invention. If a MEMBER exercises its right to a non-exclusive license, the MEMBER shall inform

UNIVERSITY of their intentions within 90 days of receiving or accessing the subject invention disclosure, and MEMBER shall pay its pro rata share, divided evenly among all MEMBERS who choose to exercise their rights to a non-exclusive license of the subject patent, of patent application, prosecution, and maintenance costs, or copyright registration costs quarterly, as defined in a separate agreement with UNIVERSITY to be negotiated at that time. MEMBER rights to a non-exclusive license to patentable inventions and copyrightable materials shall be subject to the conditions of MEMBER exclusive or exclusive for a defined field of use license rights as defined below.

Rights of Member for Negotiation of Exclusive License - All patentable inventions and copyrightable materials conceived or first reduced to practice by ERC personnel in the course of research conducted at ERC shall have title vested in the home university(ies) of ERC supported researcher(s). MEMBER may request an exclusive or exclusive for a defined field of use, royalty-bearing license for patented or patent pending inventions or copyrighted materials developed hereunder within 90 days of receiving or accessing the invention disclosure. UNIVERSITY agrees to consider such requests to negotiate with MEMBER(S) on exclusive or exclusive for a defined field of use, royalty-bearing license(s). Should such license(s) be granted, granting of all other non-exclusive licenses for in-house use to other MEMBERS shall be with-held to the extent that exclusive license(s) require. MEMBER shall pay its prorata share, divided evenly among all MEMBERS who choose to exercise their rights to a license of the subject patent, of patent application, prosecution, and maintenance costs, or copyright registration costs quarterly, as defined in a separate agreement with UNIVERSITY to be negotiated at that time. UNIVERSITY will not unreasonably withhold granting said exclusive or exclusive for a defined field of use license(s).

All exclusive licenses granted in accordance with this provision shall include the right for MEMBER to sublicense to its subsidiaries in accordance with any and all applicable State or Federal laws and/or statutes. Each such sublicense shall be subject to the terms and conditions of the license granted to MEMBER by UNIVERSITY. ERC agrees to promptly notify all MEMBERS of any request for an exclusive or exclusive for a defined field of use license to use any patentable invention or copyrightable material developed by the ERC.

Sublicense to a Third Party - The issuing of a sublicense by MEMBER to a third party to use any patented invention or copyrighted material developed under the auspices of the ERC will be subject to a royalty bearing license agreement to be negotiated with the appropriate ERC UNIVERSITY.

Use of Patented Inventions or Copyrighted Materials by UNIVERSITY - UNIVERSITY shall be free at all times to use patented inventions or copyrighted materials for educational and university research purposes only.

Reasonable Commercialization Efforts - Because of the public interest that pervades UNIVERSITY research programs, any license entered into by UNIVERSITY will embody a clause permitting cancellations thereof if reasonable commercial use of the licensed invention or copyrighted material is not being made or diligently attempted by the licensee.

Publication of Research Results - Publication of ERC created research results is of fundamental importance to universities, faculty members and their research programs. Therefore, UNIVERSITY reserves the right to publish in scientific journals the results of all research performed at the ERC (excluding proprietary information received from MEMBERS), giving due consideration to scheduling such publications in order to allow time for obtaining appropriate patent or copyright protection for any patentable invention or copyrightable materials that might result from the research. UNIVERSITY agrees to provide a copy of all experimental data resulting from research in ERC program to MEMBER representatives on the IAB for review prior to publication. MEMBER may request delay of the proposed publication of said data for a period not to exceed 90 days from the date of submission or presentation to MEMBER. MEMBER agrees to request said delay only in order to permit the filing of appropriate documents (i.e., patent application, copyright registration, etc.) on any patentable invention or copyrightable materials made by ERC, and MEMBER must make said request in writing, including justification thereof, within 30 days from the date the experimental data was presented or transmitted to MEMBER. Should the proposed publication be a student thesis or dissertation, UNIVERSITY and MEMBER hereby agree to use their best efforts to complete all reviews of material contained therein and any necessary intellectual property protection filings so as to not impede the completion of activities satisfying graduation, degree, or publication requirements by such a student.

Rights to Future Developments - MEMBERS who develop a specific technology based on basic data provided by UNIVERSITY are entitled to any derived patent(s) or copyright(s) without compensation to UNIVERSITY.

11. The parties agree to comply with all applicable State and Federal laws and/or rules concerning equal opportunity and non-discrimination.
12. MEMBER shall not use the name of UNIVERSITY or ERC in any advertising or promotional material without the specific written consent of UNIVERSITY and vice versa. A general exception is hereby granted to MEMBER to use the name of ERC and to cite the fact that ERC is operated by UNIVERSITY in written advertising and other promotional materials provided that: (1) such use is limited to describing the MEMBER relationship to ERC as herein defined by this Agreement, (2) no endorsements by ERC or UNIVERSITY of MEMBER products or other commercial activities may be reasonably inferred from such use, and (3) such use does not represent that a partnership, joint venture or other legal entity has been formed between and among the parties to this Agreement.
13. The relationship between MEMBER and UNIVERSITY shall be that of independent contractor. As an independent contractor, MEMBER assumes all risk and liability for injury to persons or damage to property caused by acts of its employees during the period of the Agreement while they are using facilities or equipment owned and/or controlled by UNIVERSITY. This Agreement shall not constitute either UNIVERSITY or ERC as agents or legal representatives of MEMBER. UNIVERSITY assumes all risk and liability for injury to persons or damage to property occurring during the period of the Agreement and caused by the acts of its employees while performing work at MEMBER's facility under the terms of this Agreement. The obligations of UNIVERSITY hereunder shall not apply to liability arising from use of information furnished pursuant to this Agreement.
14. All noted confidential information submitted to UNIVERSITY by MEMBER will remain as such unless written permission granting public dissemination is received and vice versa.
15. The provisions contained herein constitute the entire Agreement and supersede all previous communications or representations, either verbal or written, between the parties hereto with respect to the subject material hereof. This Agreement may not be changed, altered, or supplemented except by written amendment hereto, signed by all parties. It is further agreed that nothing contained in the Agreement shall modify, amend, or supersede any prior or subsequent arrangement between MEMBER and UNIVERSITY with respect to activities outside the scope of this Agreement.

IN WITNESS WHEREOF, this Agreement is effective as of the last date of signing set forth herein below, which day and month in subsequent years in which MEMBER adheres to the terms of this Agreement shall be called the anniversary date of this Agreement.

UNIVERSITY MEMBER

Authorized signature Authorized signature

Title Title

Date Date

Initial to indicate appropriate partnership category:

MEMBER $XX; $XX; $XX

[1] While this sample agreement is intended to an example of the structural framework of an agreement, the actual language in the agreement should be developed in conjunction with the university's legal counsel.

Source URL: https://erc-assoc.org/content/chapter-5-industrial-collaboration-and-innovation