Chapter 9: Multi-University Centers

9.1 INTRODUCTION AND OVERVIEW

Since 1998, NSF has funded only *multi-institution* Engineering Research Centers (ERCs) for two reasons: in order to gain the broadest possible impact in research and education, and to maximize the capabilities of research teams without limiting the Center's vision. This requirement means that to all of the day-to-day challenges of operating an industry-oriented, multidisciplinary Center on a university campus are added the extra dimensions—geographic, logistical, administrative, legal, cultural, and psychological—of requiring separate institutions to collaborate closely. This chapter focuses on the issues, challenges, and best practices that are unique to the multi-institution Center. Thus, it overlays and augments the other chapters of the Best Practices Manual, cutting across all the functional and program areas described there.

Loosely paralleling the structure of the Best Practices Manual as a whole, this chapter addresses the following topics. Links take the reader to that section.

2. Organizational Structure and Center Management
3. Administrative Management
4. Research Program Management
5. Education Program Management
6. Industrial Collaboration and Technology Transfer

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9.2 ORGANIZATIONAL STRUCTURE AND CENTER MANAGEMENT

The Center Director faces a number of challenges at the start of an Engineering Research Centerâ€™s life cycle. Initial task

delegation and staffing decisions are vitally important to smooth operation and sustained success. The Director must determine which management and operations functions to delegate during the planning stages and through the start-up phase of the ERC, as well as the level of delegation. A multi-university ERC Director also encounters the significant challenges of delegating responsibilities for campus-level activity coordination. The initial decisions regarding the fundamental operating structure of the ERC are crucial to determining its success and ensuring active collaboration among programs, thrust areas, and institutions.

9.2.1 Identifying and Forming the Center Leadership Team

At its inception, an ERC is often strongly reflective of the Directorâ€™s personal vision. The Director usually has initiated the effort and recruited the key researchers. Often, the Director brings a strong background of experience in leading large, well-funded research efforts such as a single campus-based research group. When making the transition to a newly-funded ERC, the Director must be willing and able to integrate personal goals with the Center concept, and to delegate responsibilities within the Center as it begins to progress toward the first important National Science Foundation (NSF) review. Three pivotal decisions faced by a new ERC Director include: selection and cultivation of the leadership team, delegation of various responsibilities to the leadership team, and distribution of leadership responsibilities across campuses.

During the ERC proposal process, it is critical that the senior-level university administration be recruited first, so as to ensure commitment, entice career-minded individuals to participate, and develop the support structure for partnership in all facets of the Center. Strong relationships between the Center and the lead university administration are also important to ensure establishment of similar support structures on partner campuses. As this process occurs, it is important to aggregate administration supporters under a common governing or advisory organization so that the support is nurtured and maintained throughout the life of the Center. This governing body should also be actively engaged in responding to issues and challenges raised by industry or through the NSF review process, so that resources particular to individual institutions are appropriately leveraged and concerns are addressed across institutional boundaries. Throughout its lifetime, the ERC should be envisioned and promoted as a permanent part of the participating universities and their individual strategic plans.

When forming the leadership team, the Director must consider the long-term Center life cycle, assessing the commitment of individuals to the success of the *Center* rather than to their individual goals, as well as the ability of those individuals to collaborate effectively over the long-term. Leadership roles for individuals geographically separate from the lead institution should be clearly enumerated, documented, and periodically reviewed to ensure effective management and collaboration. The Director must also recognize that the original leadership group will affect the future nature of the Center and the evolution of the strategic plan. As part of the long-term view of the Center, the Director must consider the eventual transition of top leadership and cultivate, throughout the life of the Center, an environment and synergy in which this transition can be made successfully.
As part of the recruitment and selection process, the Director must seek out specific talents and personality characteristics that are essential for the success of the team. An informed Director will recruit individuals with a team mind-set, a reputation for successful relationship-building with colleagues and university administration, and an established reputation for research leadership. Individuals with unique talents and who are prepared to be a part of the team top the list of recruits and can serve as catalysts for recruiting others, both in their home institutions and Center-wide. Recruiting talented individuals also requires the ability to balance â€œlone rangersâ€• and talented team players, realizing that personality characteristics are deeply ingrained and ultimately will affect the productivity and overall success of the Center. The Director must be mindful that diversity in the leadership team is essential and best seeded early. It is also essential that all leadership team members understand that the likelihood of organizational and personnel changes during the life span of the Center is quite high, and that the concept of the Center must be sufficiently broad to incorporate these changes.
The role of the Deputy Director in a multi-university ERC leadership team is vital to the success of the Director and the Center. The Deputy Director should augment the expertise of the Director in terms of the core research thrusts of the Center. The two primary authors of the center need to build the breadth and depth of the Centerâ€™s focus. Ideally the Deputy is a senior faculty member, often at a different partner institution. Such an arrangement cements the involvement of both institutions in the Center. The ERC will function more effectively if the Deputy can step in for the Director when needed. The more credible the Deputy is as a leader, the more flexible the management structure can be. If the Deputy can manage, lead, and be responsible for several key strategic goals of the Center, the Center can move forward more effectively with its strategic plan.

***CASE STUDY:**, Bahaa Saleh is the Deputy Director for CenSSIS. He is a senior faculty member at BostonUniversity (BU), while the Center is led by NortheasternUniversity. Prof. Saleh is the leader of one of the fundamental science research thrusts dealing with advanced sensing concepts. He is also responsible for overseeing the development of a unifying framework for subsurface sensing and imaging systems. This framework*

is a key long-range system-level strategic research deliverable for the Center. Moreover, he is leading the development of an undergraduate textbook on subsurface sensing and imaging concepts. This is a key education deliverable of the Center. As the Chair of BUâ€™s Electrical and Computer Engineering Department, Prof. Saleh has significant administrative experience and the seniority to provide leadership to the center when the Director is unable to do so.

9.2.2 Establishing Institutional Partnerships

In a multi-institution ERC, it is essential to develop and foster strong administrative relationships within and among the cooperating colleges and departments of the partner institutions so that the vision and the strategic research and diversity plans can be implemented and can evolve as needed. Therefore, successful commitment from partner universities throughout the lifetime of the ERC is key to institutionalization and is essential for the survival of the Center after graduation from the ERC program.

As keeper of the ERC vision, the Director is best suited to promote the Centerâ€™s driving concepts and to garner support for external institutions as partners. The intimate involvement of other academic departments within the lead university and partner universities at inception is vital, building toward critical reviews. Senior administrative support of the lead and partner institutions is necessary for establishing long-term institutional partnerships, and an intercampus Governing Board (GB) or similar organization can be quite useful in engaging these constituencies to sustain the Center. Such a Board can and should play an important role in establishing a common set of practices and procedures to maintain intercampus research and education endeavors, including intellectual property (IP), distance learning, and student and faculty exchange. In such cases, working relationship agreements should be formalized, signed by all parties, and recorded. The resulting agreements should be accessible and reviewed periodically as a group.

CASE STUDY: *The Center for Power Electronics Systems (CPES) Memorandum of Understanding (MOU) established a pool of industrial funds from which to select and apply for patents.*

As the number of new technologies generated by CPES grew, it became apparent that the established IP evaluation process was cumbersome and inefficient. Missed deadlines resulted in valuable technologies becoming part of the public domain. After considerable exploration and negotiation, Dr. Fred Lee, CPES Director, proposed a potential remedy to industry and officials at the partner universities. The essence of the idea was to streamline the IP review procedure and expedite the IP protection process by utilizing pooled resources from participants. The idea evolved into an agreement for implementation of a system to pool resources for the protection of selected technologies and is now known as the Intellectual Property Protection Fund (IPPF). An IPPF agreement offers participants the undisputed IP advantage of a nonexclusive, nontransferable, royalty-free license after a two-year exclusivity period. Companies that choose not to participate in the IPPF option continue to follow the standard procedure to gain access to CPES technologies. If IPPF pool participants and non-IPPF participants are interested in protecting the same technology, the cost is equally shared. Since the implementation of IPPF, 20 companies have participated to provide protection for 24 CPES technologies.

Examples of basic agreements and other organizational documents include: Strategic Plan, Operations Policies and Procedures manuals, Industry Consortium Agreements, Intellectual Property Agreements, Curriculum Cross-Listing Agreements, Student/Faculty Exchange Program Agreements, Course Credit Earnings/Transfer Agreements, and a Student Leadership Council Constitution. Examples of these documents can be found in other chapters of the Best Practices Manual or obtained from other ERCs.

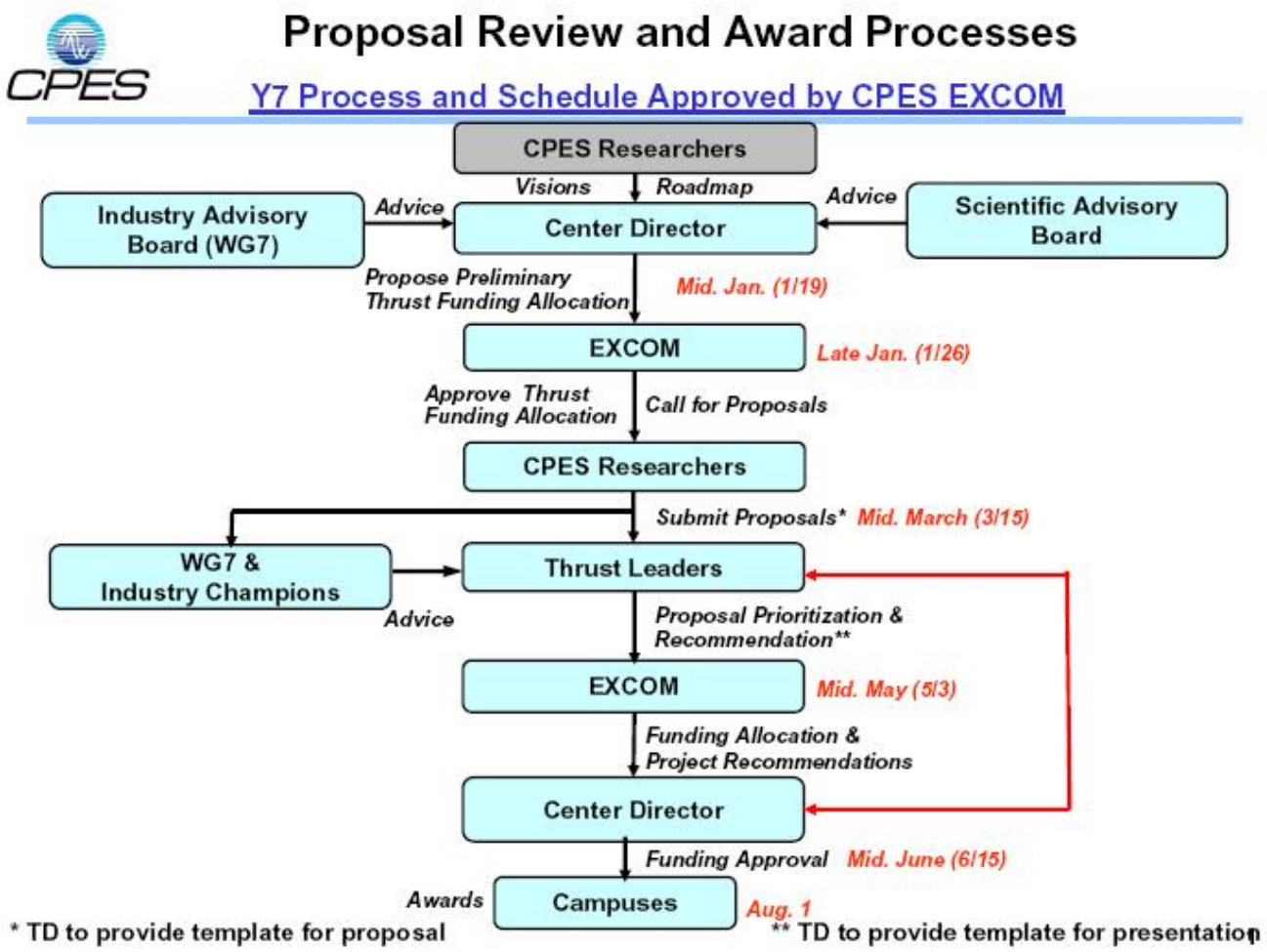
9.2.3 Initial Strategic Planning: Organizational Considerations

A first task of the newly-assembled leadership team is to review, develop, and refine the initial strategic plan to address the research, education, outreach, and diversity missions of the ERC. The initial strategic plan is usually the result of a collaborative effort and a democratic process. During this process, the Center leadership team must ensure that the plan maintains a systems focus and addresses development of all programmatic components, focusing particular attention on those areas that will be benchmarked as a part of the Centerâ€™s reviews by NSF and industry. In a multi-institution Center, the process may involve discussion and input from faculty and staff, advisory groups, and ultimately, review by representatives

from each participating institution prior to submission to NSF for approval. A facilitator or consultant might be useful in this process. The Centerâ€™s organizational structure could also include a Research or Technical Director who can assist the Center Director in review and implementation of the research strategic plan.

The strategic plan should be viewed as a living document and updated regularly to reflect changing priorities during the Centerâ€™s life cycle. The Director develops a systematic plan to revisit the strategic plan with the leadership team and Center Principal Investigators (PIs) on a regular basis, so that input from review panels and advisory bodies can be incorporated as appropriate. The Center may also form new outreach initiatives with academic institutions and/or government laboratories. These relationships will likely provide an opportunity to incorporate new expertise into the Centerâ€™s programs, including the strategic plan. It is therefore essential to develop a well-defined mechanism to review the progress of programs, individual projects, and thrust areas as part of the funding allocation process, and to review and revise the strategic plan to reflect the evolution of the Centerâ€™s work and inter-institutional connectivity over time. Factors for consideration include the channels and means of collecting internal input, as well as engaging Center faculty, thrust and program leaders, and industry and scientific advisory groups.
In managing a large multi-disciplinary research program, it is very important that each team member in each task/thrust/program understands the integrated system goals and is able to relate individual research activities to the overall Center research objectives. Each individual is a part of the ongoing communication effort that must occur to ensure that there is a mutual understanding among all participants, from the malleable student to the seasoned researcher.

Case Study: *CPES uses many tools to facilitate an integrated culture. The development of an all-encompassing roadmap that clearly delineates the interdependencies among the thrusts and is supported by milestones and benchmarks at each thrust level is the single most powerful tool. This roadmap is reviewed, discussed, and updated as part of an annual CPES Research Retreat that involves all faculty research leaders from all the partner campuses. Further, weekly project meetings attended by all faculty and students involved provide an opportunity for the students to reinforce understanding of the overall activities and to foster team collaboration. The key to success is frequent and productive communication and interaction among all Center members, using telephone and web conferencing tools. These interactions establish a basis for individual appreciation of outcomes that are achievable when acting as part of the team.*



9.2.4 Allocation of Funds

Establishing budgets/funding allocations is a major process that must be addressed at the Center Executive Committee level and requires time to refine. Funding cannot be allocated on either a pro forma or entitlement basis. In addition to the concerns of allocations across programs, disciplines, and research thrust areas, multi-university Centers also face the unique challenge of reviewing and allocating budgets across institutions. Cost-sharing commitments must be made and met at each institution, while remaining balanced against expected and actual outcomes. In a multi-university environment, it is therefore necessary to develop a process which addresses all internal parties such as thrust leaders, campus directors, program directors, and PIs, while also reflecting the input of the Industrial Advisory Board (IAB) and the Scientific Advisory Board (SAB), as well as other applicable external consultants or stakeholders. The Directorâ€™s role is critical to ensure that the process and outcomes reflect the multi-institutional nature of the ERC. In particular, the Directorâ€™s perspective is instrumental in ensuring that the research review process considers not only technical connectivity within and among projects and thrusts, but also supports ongoing intercampus connectivity.

Fig. 9.2.1 Sample Research Review Process Flow Chart

Figure 9.2.1 shows the research proposal review and funding process at CPES. The timeline allows for input from the five campuses of this Center and their representatives on the Centerâ€™s Executive Committee (ExCom).

9.2.5 Principles and Practices for Managing the Multi-university Center

Overcoming geographic, institutional, and cultural distances within a multi-university Center requires open and regular communication at all levels. The cultivation and maintenance of relationships is a priority throughout the life of the Center. Achieving collaboration toward a common goal (and suppressing unproductive competition) is largely dependent on the Director and is a task that grows exponentially with the number of involved individuals. While the Director should avoid processes that are excessively democratic, consensus decision-making methods and implementation are fundamental to fostering an open and constructive environment within the Center. Essential staff members can play a vital role in supporting this environment by their responsiveness and flexibility.

From Center inception, the Director should be mindful that participation in an ERC will require attitude adjustments and a deep level of personal commitment from all participants. Key faculty must commit to a substantial administrative load, including strategic planning, cross-campus project coordination and reporting, as well as administration of their own research projects. Given the administrative complexities and the need to develop programs and relationships consistently over time, long-term commitment of these faculty members is essential to Center success. Commitment to long-range planning and outcomes is required of participants at all levels. For participating faculty, transformation of the individual PI mindset to one of interdisciplinary team play is a challenge. In multi-university ERCs, participation is as a Center partner, rather than an as a separate institution involved in a Center. Being an ERC partner is a cultivated behavior.

Data collection, interpretation, presentation, and access pose significant challenges in multi-institution ERCs. The lead institution should be prepared to provide technical infrastructure to facilitate this information exchange; to interpret and clarify reporting guidelines for individuals and offices at lead, core partner, and outreach institutions; and to identify common platforms for intercampus communication. Scheduling across time zones and multiple faculty class schedules is often challenging. For this reason, it is best to establish in advance long-range schedules for critical meetings.

9.2.6 Planning and Delivering on Diversity Goals

From the establishment of a Center, gender equity and ethnic diversity need to be embedded in the education and outreach goals as well as the faculty and staff recruitment goals. During the first year the Diversity Coordinator needs to convene an Education and Diversity Advisory Board (EDAB) (or the equivalent) representing the Centerâ€™s partner institutions and strategic corporate partners, and supplemented by nationally recognized experts in these fields. The EDAB or a subset needs to develop a strategic plan for diversity across all the partner institutions and to integrate key elements of the plan into strategic planning discussions of the Centerâ€™s Executive Committee.

During the second year, the EDAB or subset should develop a strategic planning process to help the Director set realistic goals and workable strategies for significantly increasing diversity in Center laboratories and classrooms. The core of the process is the development of a Strategic Plan for Diversity. Key elements of this plan are:

Get accurate baseline data and set realistic five-year diversity goals for increases in the percentage of females and racial and ethnic minorities represented among the Centerâ€™s faculty, graduate students, and undergraduate students

- Designate strategic activities that will assist in reaching established goals
- Provide sufficient resources to adequately fund designated activities
- Develop a flexible funding strategy for efficient deployment of resources
- Establish specific patterns of responsibility and accountability
- Collect accurate annual data (separately by partner institution, and totals for the ERC)
- Supplement annual data-gathering with interim reporting requirements as needed
- Create a mechanism for the diversity program to report to key stakeholders at both lead and partner institutions, such as the Governing Board or Advisory Board.
- Leverage existing institution-level initiatives at lead, core partner, and outreach institutions
- Engage in continuing project evaluation.

CASE STUDY: *The CenSSIS six-year results demonstrate that if a strategic planning process is applied to increasing the numbers of females and minorities in an ERC, increasing diversity is possible. For example:*

- *The number of female faculty increased from 6 (13%) in Year One to 18 (30%) in Year Six. The number of minority*

faculty increased from 7 (12%) in Year One to 19 (31%) in Year Six.
- *The number of female graduate students increased from 9 (23%) in Year One to 34 in Year Six. The number of minority graduate students increased from 10 (8%) in Year Four to 31 (28%) in Year Six.*
- *The number of female undergraduate students increased from 37 (41%) in Year 5 to 38 (41%) in Year Six.*

9.3 ADMINISTRATIVE MANAGEMENT

Administrating a multi-institution Engineering Research Center (ERC) involves several special challenges. Paramount among them is building and maintaining a strong relationship among the academic, strategic, and industrial partners.

Effective communication is the key to maintaining a cohesive and focused Center. The management teams—Governing Board, the IAB, the SAB, research managers, education program directors, outreach coordinators, industrial liaisons, and administrators—need to understand their roles and objectives in the changing environment typical of the ERC. Weekly management team meetings, composed of members of all the groups within the ERC, keep everyone on the same page. Regular meetings of the GB, IAB, and SAB tune the strategic focus.

The ERC events (IAB meetings, Center-wide research symposia, Retreat, NSF ERC program annual meeting, NSF Annual Report, and Site Visit) are coordinated efforts that require the cooperation of academic, strategic, and industrial partners. The administrative and financial infrastructure must be designed to be flexible and robust.

9.3.1 Administrative Challenges Unique to Multi-Institution ERCs

The challenges for multi-institution ERCs are obvious. They are more intricate organizations, composed of many institutions with different systems, complex administrations, and varied financial needs and accounting systems. Getting things done requires cooperation, communication, and talented administration.

9.31.1. Increased Complexity of Multi-institution Centers

There are many aspects of this greater complexity:

- There are additional stakeholders and layers with differing priorities, agendas, and institutional cultures.
- There is an increased need to manage expectations when there are competing demands for resources, i.e., balancing the Center's core work of producing research results and educating a diverse future engineering workforce with creating and maintaining the management and administrative infrastructure needed to accomplish both that work and NSF deliverables.
- Process- and consensus-building takes more time, effort, and shepherding at all levels, but is critical to achieving the collegiality and cohesion needed to think and work as a Center, versus with an institution-specific mindset.
- The cost of doing business (e.g., administration, operations, marketing expense) is higher and requires a larger percentage of funding. Managing a geographically distributed enterprise with multiple partners requires a more sophisticated administrative structure and additional resources. For example:
- Administrative overhead/infrastructure funds for administrative personnel, facilities, and information technology support are needed (at least part-time) at each campus.
- There are substantial travel-related costs (hotels, airfare, and meals) for Center-wide events such as NSF Annual/Renewal Site Visits and IAB Meetings, the NSF ERC Annual Meeting in Washington, D.C., and periodic Center operating meetings such as Retreats and Executive Committee Meetings.

CASE STUDY: *Each core partner institution of the Center for Subsurface Sensing and Imaging Systems (CenSSIS) is usually represented by approximately 20-25 faculty researchers, students, and senior administration personnel at its annual NSF Site Visit and annual Research and Industrial Collaboration Conference; smaller groups meet in person at other times during the year.*

CASE STUDY: *At CPES, the NSF Site Visit is held in conjunction with the Center's Annual Conference and*

review by industry. The Annual Conference, which includes tutorials, invited presentations, technical sessions, a poster session, and industry-student forum, is organized by a multi-institutional committee of students. The CPES Annual Conference typically attracts approximately 250 attendees per year from around the world. In recent years, this annual event also provides a forum for strategic planning workshops involving industry as well as faculty and students from lead, core partner and outreach institutions.

Tip: Consider scheduling IAB meetings and NSF Site Visits back-to-back to minimize travel-related and other costs. Since Site Visits may be conducted at the partner institutions, rotate the fall IAB meeting among partners to spread the burden and maximize industrial members' familiarity with the Center's "branches."

- Telephone conference calls needed to conduct the Center's administrative business, research, and technology transfer increase the cost of doing business.
- Infrastructure at the university level for administrative/operating support can vary greatly from institution to institution. Expect the Center to build, buy, or outsource solutions for Center operations to meet NSF deliverables, which are unique and complex.

9.3.1.2 Agreements Between and Among the Partner Institutions

At a minimum, the lead institution will enter into a subcontract with each of the partner institutions to provide them with their NSF ERC and industrial funds and bind them to the requirements of the Cooperative Agreement with NSF.
Many multi-institution ERCs also execute a Memorandum of Understanding (MOU) among all the partners. This agreement can address a range of issues but almost always includes a statement about how the Center's intellectual property (IP) will be handled.
The lead and partner institutions also need to agree on how the industrial partnership agreements between the Center and an industrial partner will be handled. Typically, these agreements are signed by the lead institution on behalf of all the partners but the policy needs to be clarified and documented by mutual agreement among the partners.

CASE STUDY: *CenSSIS established an Academic Partnership Agreement from the onset that was executed by the lead partner and the other three partner institutions; the CenSSIS Academic Partnership Agreement points to the Center's Industrial Partnership Agreement that is executed with member companies. A separate Intellectual Property Agreement was drawn up by the ERC's Industrial Liaison Officer and the lead university's Technology Transfer Office after substantial discussion with all the partner institutions.*

CASE STUDY*: CPES established intercampus agreements for Distance Access of Courses and Exchange of Graduate Students. In preparation for graduation from the NSF ERC program, CPES also established an intercampus agreement for continued post-award collaboration of the lead and core partner campuses.*

9.3.1.3 Effective Communication Is Key to Achieving Multi-institution ERC Cohesiveness and Focus

Multi-institutional weekly meetings via teleconference or videoconference are critical to operational success. Timeliness and frequency of meetings are important considerations. It is best to establish a consistent time and place, where appropriate, so meetings become routine.

CASE STUDY: *CenSSIS has a weekly management meeting accessible via a toll-free call-in number that is open to a broad constituency. The Director is highly involved in shepherding these meetings and personally emails out the agenda in advance and the meeting minutes afterwards. He often contacts key personnel beforehand to encourage meeting participation by remote attendees.*

Tips:

- Encourage participation by key people.

- Prepare and follow an agenda that is sent out in advance.
- Follow up with minutes and action items.

Face-to-face meetings throughout the year in addition to those required by NSF increase the quality of communication.

CASE STUDY: *The CenSSIS Executive Committee meets two to three times annually to make funding allocation and other high-level, Center-wide decisions. One of these meetings is the Strategic Planning Retreat attended by the Center's Senior Management, key researchers, and BOD (composed of partner deans and strategic industrial/government partner members).*

CASE STUDY: *CPES conducts a weekly management meeting which involves all key personnel within the leadership team. The CPES Executive Committee, which includes all leadership team members, campus directors and thrust leaders, meets on a monthly basis. Discussion topics include: upcoming events, annual reporting, funding allocations, strategic planning issues within the Center's research, education, and industry collaboration programs, and other Center-wide decisions. Each November, a retreat is conducted for all Center PIs to discuss strategic planning within the research program.*

Information technology is the tool that the local and distant partners use to generate, communicate, and store their information. The local area networks (LAN), Internet, and the associated administrative staff are indispensable to a multi-institution ERC.

Electronic media—email, internet, file transfer protocol (FTP) and WebEx—are timely, inexpensive, and useful to expedite communication.

CASE STUDY: *At CenSSIS, email is the predominant means of communication among academic, strategic, and industrial partners, used to announce events and transmit the CenSSIS newsletter.*

The Internet and the CenSSIS website are used to keep partners and interested parties aware of the work being done and informed about the calendar of events. The Internet is also used to obtain data (registration and personnel information) and distribute it (forms and documents).

The FTP site is used to obtain and send large files between CenSSIS partners.
WebEx is used for sharing documents in real time, distance learning, seminars, and video conferences.

CASE STUDY: *Beginning approximately a calendar quarter prior to the NSF Annual Report due date, CPES has a weekly conference call for administrators only, as a forum for discussion about data collection, documentation, and reporting.*

Tips:

- Explore and use appropriate tools and technology to facilitate administrative communication.
- The Administrative Director should participate in the meetings related to formulation and review of the Annual Report.
- The Administrative Director should become familiar with the NSF ERC library (part of the ERC website operated by NSF contractor QRC), enhancing access to and consideration of NSF-ERC outputs, including Annual Report guidelines and the ERC database.

9.3.1.4 Multi-institution ERC Activities Are Complex

ERC activities (Retreat, Site Visit, Center-wide conferences, Annual Report preparation, and IAB, SAB and GB meetings) occur during the academic year (September through May). The ERC's calendar should be created two to three months before the beginning of the academic year. It is important to schedule the ERC's activities so that (if possible) the ERC is not conducting more than one activity at a time. Further, it is important to avoid institutional event conflicts.

Creating a multi-institution ERC calendar can be a challenging process.

Tips:

- Establish calendar dates for events and deliverables as early as possible in the year and make the event timing as consistent as possible from year to year. Cementing mutually agreeable dates can be difficult to accomplish with multiple institutions and different academic calendars.
- Institute mechanisms and timelines to report data (via QRC, the NSF database contractor) and in print form) to NSF centrally by lead partner, but with input and supporting documentation from partner institutions. Personnel activities can be more difficult to track with multiple contributing institutions, particularly for students and more ancillary Center contributors.

CASE STUDY:*To prepare for Annual Report data submission, CPES disseminates to all contributors a complete copy of the report and indicator table guidelines as soon as the final versions are received from NSF. This provides an electronic template and detailed instructions for data submission based on NSF expectations. Each partner university is asked to submit the required data PLUS back-up documentation for each item to a centrally-administered ftp site that is established specifically for this purpose. Contributors and advisors have access to the FTP site and can provide input or suggestions for refinement throughout the development of the report document. The back-up documentation is required for file record and to ensure that the data submitted has been thoroughly reviewed by the submitting institution for applicability and correctness. Approximately six weeks prior to the Annual Report deadline, the CPES Executive Committee meets to jointly review and discuss the data and text submissions, both as component parts and as a whole. In the six weeks following this review meeting, CPES centrally gleans each partner institution's data submission, checking for errors, duplication, or inconsistencies with current or previously gathered information. Communication with the partner institutions during this period is via any and all means available, frequent, and quite detailed to ensure accurate reporting of the activity, both during the reporting period and cumulatively. Finally, the data are finalized in the indicators database and submissions are merged by CPES central into the final NSF-prescribed format.*

CASE STUDY: *At the VaNTH ERC, partner institutions begin working on data submission approximately four months prior to the Annual Report deadline. Templates and instructions for the tables required for the indicators database and the Annual Report are developed and provided to each partner institution at approximately two-week intervals. In particular, the instructions emphasize the reporting periods for financial and non-financial data. Individual deadlines are established for each of the tables and data for a particular table are analyzed and verified before the template for the next table is provided to the partner institution. As tables are completed, the Administrative Director atVanderbiltUniversity (the lead institution) accumulates the data in linked Excel spreadsheets for each of the VaNTH institutions into the combined table that is required for the indicated database.*

9.3.1.5 Multi-Institutional Education Programs, Diversity Programs, and Financial Systems

Education programs at a multi-institution ERC can be difficult to establish and operate. Institutions may be on semester or quarter calendars. Course set-up is similar to that at single-institution ERCs, but agreeing on course credits, registration process, course calendar, and course execution can be challenging. Agreeing on a lecture forum (real-time webcast, videotape, etc.) can be an issue, as can implementing the forum.
Establishing a diversity program can vary in difficulty across ERCs, depending on the maturity of the diversity programs at each institution and institutional support of the effort.

Developing a financial system for a multi-institution ERC is difficult. The various institutions and NSF all have different accounting, reporting, and calendar systems and treat overhead, fringe, capital, expense, and travel differently. Each institution typically provides different information in a different form from a different software program. The NSF calendar and reporting period often do not coincide with those of the institutions and may change during the life of the grant. In a multi-institution ERC, receiving relevant information on schedule is also problematic. Finally, inputting the financial information from the multiple institutions into the NSF annual reporting system is difficult.

9.3.2 Structure and Roles of the Administrative Staff

An administrator is required at each partner's location to expedite communication and coordinate Center activities. The

administrative staff performs a variety of tasks to carry out the Center's business. The same tasks continue during the life of the Center, but the amount of effort needed in each area varies and the staffing level required to complete the tasks varies accordingly.

9.3.2.1 Functional Elements

A mature multi-institution ERC needs sufficient staff to carry out the following administrative tasks, programs, and activities:

- General Office Management and Administration
- Conference and Events Planning and Management
- Information Technology Planning, Development, and Management
- Database Planning, Development, and Management
- Accounting/Financial Planning, Development, and Management
- Program Grant/Contract Administrator
- Graphic Arts Support

9.3.2.2 Lead Institution Staffing

Normally this comprises at minimum two full-time administrators at the lead institution (and often more). Dedicated (at least part-time) administrative support and grant/contract personnel are necessary at the lead institution to administer the NSF contract and assist with the budget/accounting.

9.3.2.3 Administrative Staff at Partner Institutions

There should be an administrative staff member at each partner institution to expedite the necessary financial, personnel, and other data for the Annual Report; assist with event planning; and provide a central point of contact for ERC faculty, staff, and students. Without such administrative support, partner faculty will need to provide a wide range of data and services to support the ERC activities.

CASE STUDY:*When the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) became an ERC in 2003, the University of Puerto Rico at Mayagüez (UPRM), a CASA core partner, established a central ERC office that supports not only CASA, but also UPRM's three other ERCs, CPES, CenSSIS, and the ERC for Structured Organic Composites at Rutgers. This enables highly beneficial teaming and sharing of knowledge and approaches.*

9.3.2.4 Staffing for Center Life Cycle Stages

Start-up Stage: Minimal staff, analogous to a business venture start-up. Start staffing up and establish systems early, optimally before NSF ERC funding begins, so that the Center is positioned to get off to a good start and hit the ground running. This can help preclude complicated, time-consuming problems later.

Ramp-up Stage: Period of Center growth and specialization of administrative job functions. Particularly needs to be well staffed by the end of years one and two as the Center moves toward year three renewal, a major Center milestone.

Steady State: Begins at approximately year four, as work proceeds towards year six renewal through approximately year eight.

Ramp-down Stage: At about years eight through ten and beyond, preparation for self-sufficiency intensifies in anticipation of NSF's phase-down of support and graduation after year 10. Administrative support must meet the NSF deliverables contract. The needs at this stage tend to center on financial/accounting, personnel management, and information technology functions. Ideally, the Center begins to enter a new enterprise stage—e.g., a spin-off company, receipt of support from a new source—during which the administrative structure will need to be assessed and adapted.

9.3.3 Center-wide Systems, Procedures, and Operations

Established systems and procedures are needed to conduct the IAB meetings, major research symposia, Retreats, and the Annual Reports and Site Visits. Establishing a reasonable and achievable calendar is a first step.

The most time-consuming administrative event is the Annual Report. To effectively manage the Annual Report preparation process:

- Develop a database and data entry system for the personnel database.
- Develop a system for obtaining the accounting data from partner institutions.
- Develop a procedure for obtaining the project reports.

The Site Visit is the next most demanding administrative event, and arguably the most important. The renewal year visits, the third and sixth years, are crucial. The Site Visit and industry research symposium require a comparable level of administrative effort. These events require clear communication with Center partners (academic, strategic, and industrial) via effective communications media. Phone calls, teleconferences, email, websites, and ftp sites are the primary media. An important administrative function is to keep the media up and running and easy to use. Face-to-face meetings can also be important.

9.3.3.1 Annual Report Systems

The most important points and suggestions are as follows:

- Thoroughly review the current Annual Report Guidelines.
- Data collection for NSF reporting is complex and may require an individualized system at each Center. Developing a personnel database is difficult and costly. Review the Annual Report data collection system to understand the demographic and financial data requirements.
- Links to the most current versions of the Annual Reporting Guidelines and the Database Guidelines can be found on the ERC Library website at https://www.erc-reports.org/
- Detailed timelines for each part of the Annual Report, including individual project reports, proposals, and thrust reports, must be publicized well in advance. Timelines should contain deadlines for submitting initial and revised reports, and should provide adequate time for the review and selection of proposals to submit as part of the next annual funding request.
- Templates for both the project report and proposal are strongly suggested. In addition, the Center should develop a standard questionnaire for each project Principal Investigator to complete. Create a system to collect and assemble report materials by email, ftp site, snail mail, etc.

9.3.3.2 Site Visit Planning Logistics

The Site Visit usually is the one event of the year that the NSF attends. It occurs five weeks after the delivery of the Annual Report. The administrative priority is to ensure that the event runs seamlessly. The two events, Annual Report and Site Visit, form the peak of administrative activity in the year.

Arranging and preparing the written materials for the Site Visit is not difficult, because they are excerpted from the Annual Report. Every third year is a funding renewal year; hence, it is especially important for these meetings to run exceptionally well.

Practicing the Site Visit presentations with some reviewers external to the ERC is highly recommended. Commit several days to the review that can be used to strategize, practice, and edit presentations from the partners. Coming together at a single location and running through the presentations from beginning to end can be helpful, as can a Red Team (composed of the IAB and SAB) review of these presentations.

Careful attention must be given to communicating details about technical set-up (audiovisual, etc.) so that the presentations run smoothly. Make sure that presentation format requirements are well understood by all participants in advance.

Collecting presentations for printing the required Briefing Book means advanced coordination, since many participants are likely to be traveling on the day the materials are in production.

9.3.4 Maintaining Strong Relationships Among Partner Institutions

Developing and maintaining strong relationships within the multi-institution ERC is necessary to accomplish the groups' activities and goals. Communication among the partner institutions on a weekly basis maintains focus and helps to develop a multi-institutional culture.
A Center culture and orientation versus an institutional orientation must start at the Director and senior levels and permeate the organization, so that the administrative activities are carried out seamlessly throughout the consortium.

The Center needs to invest in occasional in-person opportunities for Center personnel to interact, such as Center-wide retreats and conferences, to help form relationships that will expedite day-to-day activities. This approach can be taken for smaller subsets of the ERC faculty and staff as well. For example, CPES holds quarterly campus meetings of its five Campus Directors.

The administrative staff carries out the Customer Service function for all of the partner institutions to accomplish the groups' activities. Dedicated customer service is particularly needed for a distributed Center where the partners are geographically distant and most Center business is done remotely.

Each ERC institution should have a "go-to" person who gets things done and provides administrative support. This person acts as a conduit for communicating and providing materials to the other ERC participants in the institution and to the other partner institutions.

Tips:

- Rotate the location of Center meetings among partner institutions.
- Include Administrative and Grants and Contracts personnel from partner institutions at occasional meetings to ensure that the administrative staff is acquainted with all ERC institution members.

CASE STUDY: *CPES representation at Administrative Directors' Summer Retreats has included the AD from CPES's partner institution, Virginia Polytechnic Institute, and the Administrative Coordinator from partner institution Rensselaer Polytechnic Institute.*

CASE STUDY: *CenSSIS invited Grants and Contracts personnel to planning meetings from all partner institutions; joint Center Retreats have been held near partner institutions RPI and UPRM, as well as Woods Hole Oceanographic Institution. These Retreats include the Senior Management Group and its Board of Directors.*

9.3.5 Financial Management

Creating a common financial calendar can be a multi-institutional administrative issue. It is important to recognize that there may be several different financial calendars among the partners. Institutions might be on a government, academic, or annual calendar.

Establishing the chart of Accounts and Budget Account Management Structure is critical to Center operations. It is critical that the lead institution and all of the partners understand the financial reporting requirements for the Annual Report at the outset. Each partner will have to account for funds on a project-by-project basis as well as accumulate costs to the appropriate research thrust or program as required. It may not be possible for the partner institutions to establish the same kind of accounting system as the lead institution, so the partners may need to consider an appropriate "shadow" system. This system should be reflected in the partner's invoices so that the lead can determine costs by task/thrust/program.

Cost-sharing and industrial memberships must be certified for the entire Center by the lead institution, which is the legally responsible entity for the ERC; partner institutions are considered to be subcontractors. While recognizing that partner institutions may not meet deadlines, the requirements and schedule for invoicing should still be tight; timeliness is paramount. Monthly invoicing using a standard invoice template that includes cost-sharing by task/thrust/program and line item is

recommended, certified through signature of an authorized organizational representative. This serves the dual purpose of: (1) enabling monitoring and follow-up that cost-sharing expenditures are occurring throughout the year to meet cost-sharing commitments at each institution, and therefore as a Center; and (2) facilitating reconciliation of fiscal information for the Annual Report, thereby streamlining the required annual certification of cost-sharing by the lead institution.

There are subcontract management and invoice timing implications for the Annual Report tables. It is important that the lead institution understand the requirements for reporting expenditure data in the Annual Report. The lead institution, for example, has not actually expended any funds until it has paid a partner's invoice. Therefore, if subcontractors are tardy in submitting their invoices, expenditure data for the lead will lag and cause concerns at NSF. It is important that the subcontract include language requiring timely submission of invoices.

The lead institution should work closely with the office on campus responsible for writing and issuing the subcontracts to the partner institutions. The subcontract language will help clarify the requirements that each subcontractor must fulfill, and ensure that data and certifications are available for the Annual Report. The lead institution should decide, for example, whether the subcontracts will include detailed individual task orders for each project at the partner institution or whether the partner institution will receive a lump sum to allocate to individual projects.

9.4 RESEARCH PROGRAM MANAGEMENT

An Engineering Research Center's research program is at the core of its purpose and activities. Creating a strategic research plan is vital to the Center's success. The research plan is a central part of the ERC's overall strategic plan, which also includes education, diversity, and industrial interaction elements.

Equally as important as developing, revising, and monitoring the strategic research plan is establishing the infrastructure to select and review appropriate research projects. Integrating resources and facilities to build teams whose contributions are greater than the sum of their parts also is an important part of the research effort. The testbeds around which the ERC research thrusts are crystallized provide an important focus for research, education, industrial collaboration, and technology transfer.

Chapter 4 of the *ERC Best Practices Manual* addresses research program management for ERCs in general. This subsection of Chapter 9 focuses on research management for multi-institution ERCs.

9.4.1 The Strategic Research Plan: Development and Evolution

The plan starts with an understanding of the state-of-the-art of research in the academic disciplines that converge on the engineered systems that are the focus of the ERC. It is developed in recognition of the fact that the plan will evolve. The plan is built on established organizing principles (NSF's three-plane chart, various conventional flow charts) and several leadership levels (Center Director, an overall Research Leader, and Thrust Leaders). It is important for the academic participants to recognize the correlation between changes in the plan and its funding as well as the fact that program components may be completed or phased out.

9.4.1.1 State-of-the-Art Analysis

The first step in developing the strategic research plan is to assess the state-of-the-art in the field. This analysis should be updated continually and the Center's contributions documented, resulting in a comprehensive history of contributions in the field. The dynamic state-of-the-art analysis should cover national and international developments, and both disciplinary and interdisciplinary literature.

This initial analysis step is part of the Center's proposal development process and defines the potential contribution that a subsequent award might provide. Continuing analyses of the state-of-the-art and the impact of the ERC's work on the field must be formally coordinated and then documented through comparisons in the Annual Report submitted to NSF. Speculation about the state-of-the-art in the field and the ERC's role in its evolution is insufficient to support continued NSF funding. Sourced references and documentation are required to justify the expectation that the ERC is not operating in a vacuum toward insular goals that may have little or no application in the global environment. A multi-institution ERC may acquire information

or documentation from multiple sources and perspectives, requiring joint discussions to reach a consensus about how the Center can be optimally integrated to achieve the maximum impact—and what impact it is having.

CASE STUDY: *The Mid-America Earthquake (MAE) Center, which is focused on earthquake risk only, reviews all literature in the risk arena in which tools and data may be available that apply directly to earthquake risk. Developments all over the world are reviewed continuously, even though the exposed societal systems might be different than those in the US.*

9.4.1.2 Nature of the Research Plan

The ERC strategic research plan is focused on both addressing fundamental, technical, and system-level barriers that must be overcome to advance the field—as defined by the current state-of-the-art assessment—and serving as a potential catalyst in the development of a new field and/or industry

CASE STUDY: *The state-of-the-art in power electronic systems at the inception of Virginia Tech's Center for Power Electronic Systems (CPES) was delimited by numerous disjunctions among the many components that comprise such a system. The CPES strategic plan laid out a roadmap that would provide the Center with the capabilities to become a world leader in power electronics through a multidisciplinary, multi-university, and multi-industrial partnership program extending over a ten-year period. The program was based on an integrated systems approach to standardize power electronics components and packaging techniques in the form of highly Integrated Power Electronics Modules (IPEM). The IPEM approach makes possible increased levels of integration in the components that encompass a power electronic system? devices, circuits, controls, sensors, and actuators. It was a new approach that took power electronics to a new level of performance.*

The level of definition of the plan will vary, depending on the field and the specific Center circumstances. For example, "The primary research goals of the Center are as follows . . ." and "The baseline for progress assessment is or will be established by . . .", followed by enough detailed information to clarify the specific areas of the field to be addressed as well as the approach for achieving success in those areas utilizing the proposed Center configuration, with special attention to the advantages gained through partnering with other institutions/disciplines and industry partners. The relationship between the primary goals and the partner institutions should be articulated and future expansion and refocusing should be discussed with regard to possible changes in the makeup of the ERC where new alliances might be sought to optimize the talents needed to achieve the research goals.

9.4.1.3 Plan Organization

Deliverables take many forms and should be identified and scheduled in the research strategy development.

A PERT chart, Gantt flow chart, or equivalent schedule of planned milestones with an anticipated target date for completion can be used to summarize the plan and its deliverables. Including details for reaching the charted milestones in the strategic document is considered optional. Anticipated barriers should be identified, specifically to facilitate incremental progress, assessment and documentation. NSF has developed a "three-plane chart" that is a useful tool for organizing and visualizing the interconnections between the fundamental research, technology demonstration, and technology/system integration levels of an ERC's work. This chart can be customized to reflect the strategic research plan in detail. It is important to have the chosen organizational tool detailed at the Project, Thrust, and Center levels with clear relationships among the three levels, both top-down and bottom-up. All ERC researchers should be committed to the deliverables and have a full appreciation of where they fit within the grand plan. The effort has to be balanced among the three planes.

9.4.1.4 Research Leader

Many multi-institution Centers find that designating a single research leader whose purview spans all the research thrusts is integral to the research plan's successful realization and evolution. This optional (but recommended) position can have a variety of titles, for example, Associate Director for Research, Deputy Director, Technical Program Director, or Chief Scientist.

The administrative burden on a single-institution ERC Director is quite heavy and increases exponentially in a multi-institution ERC. Although the Center Director might be tempted to control the research program personally, it is advisable to assign another individual to the task. There are many reasons to do so, not the least of which is preservation of the Director's sanity. These include the Director's need to maintain a macroscopic view, while the research leader is immersed in the program

details; the need for a single individual who is well-versed in the program to interact directly with the Thrust Leaders and facilitate research integration at a hands-on level; and the need to continually assess progress and failure, to coordinate reporting out, and to coordinate revisions to the plans in a thorough and progressive manner. Additionally, this individual may provide a higher degree of accessibility and linkage to partner university programs and Thrust Leaders, thus expediting forward progress.

9.4.1.5 Thrust Leaders

Thrust Leaders lead in planning and executing a thrust-level strategic research plan. They can provide the critical perspective that might reveal the gaps or barriers in the plan as well as its potential outcomes or shortcomings. Often Thrust Leaders can also offer preemptive solutions to perceived barriers, thus facilitating planning and implementation strategies. Thrust Leaders serve as the third level of research management, below the Research Director and the Center Director. Their role is critical in translating between researchers and research management to achieve the ERC's deliverables.

9.4.1.6 Annual Plan Review

Visit (and revisit) the strategic research plan and roadmap annually through a group effort involving all key faculty members, Thrust Leaders, the Research Leader, selected stakeholders, advisory boards, and all partner institutions.

CASE STUDY: *At CPES, the Annual Review begins with an annual faculty Retreat. The Retreat agenda includes a review of the Center's vision, goals, technical roadmaps, barriers/challenges, expected outcomes, and a progress assessment. Retreat conclusions are subsequently presented for discussion and/or action through routine meetings of the various advisory boards.*

9.4.1.7 Changes Affect Funding

Project and thrust area funding may be directly affected by changes in the strategic research plan. It is important that all partner institutions be aware of potentially adverse effects on their anticipated future funding levels for research and be prepared to adjust their efforts accordingly.

The documentation resulting from the process of submitting a joint proposal may create expectations for funding in accordance with the original research plan. Since changes in the original research plan are a natural and expected outcome related to the nature of basic research, it is incumbent upon partner institution leaders to ensure that the administrative units within their individual institutions are aware that the dollars included in the originally proposed research plan are not to be interpreted as an entitlement to a specific dollar award in future years and that the actual institutional award will vary commensurate with the research plan's evolution. Setting this expectation requires effective communication as well as changes in the traditional culture of post-award administration. Such administration is institutionally specific because it aligns with the ways that the data included in the original proposal are used within the institution (e.g., reporting of research dollars for an individual faculty member, department, college, or for the university at large; faculty activity and tenure review; and dollars committed in cost sharing or matching support). It is also important that all Center members share responsibility for pursuing alternative funding options for any discontinued projects that have fundamental intellectual merit and/or value in the field, but are outside the scope of the strategic plan. The ERC, mainly through its Director, should spare no effort in stressing to institutional representatives that it is in the interest of all concerned that no culture of entitlement is allowed to develop, even for an institution seen as critical to a successful proposal. Only merit reviews are the basis for continuing funding, and only projects with clear deliverables germane to the Center's should receive funding.

9.4.1.8 Phasing-Out Mechanism

It is advisable to include a phasing-out mechanism as part of an evolving research plan. This will help ensure that the impact on both students and related research projects that results from discontinuing a project or a thrust area is minimized. Phasing out a research area is more complicated in a multi-university Center and requires thorough advance coordination with Campus Directors at partner institutions.

9.4.1.9 Serendipitous Discoveries

As research program assessment occurs, it is likely that some discovery merits further examination and yet does not fall under the strategic plan, even as the strategic plan evolves to encompass changes pertinent to the core research undertaking. In an integrated multi-university environment, the decision to discontinue a particular project or thrust is generally achieved through

consensus. Some alternative paths for continuing or using the discovery may be identified in advance so that expectations are limited to realistic possibilities and group harmony is not threatened by the natural evolution of basic research. For example, there may be “seed” or “bridging” funds set aside as part of the industry consortium to temporarily continue research, or the Center may submit a proposal to industry or a government funding agency seeking support for supplemental study in a particular area. Projects that are of a highly fundamental nature should be good candidates for NSF support while those that are of a high application value should be attractive to industrial partners. If such a project falls in neither category, and is not integral to the Center’s strategic plan, it is clear that it should not be continued under the aegis of the ERC.

9.4.2 Project Selection and Review

Creating a program, thrusts within a program, and projects within thrusts is fundamental to the research effort. As the program progresses, new barriers and challenges appear, changing the scope and resource allocation. The Center Director is central to the continuous refinement or redefinition of the research program and to determining project approval and funding allocation.

9.4.2.1 Process

As the research program progresses, changes in scope, resource reallocation, and expertise shift will occur. A general process for project selection and review should be established and included in the Center’s policies and procedures manual for reference.

The plan and scope of the research are fluid for much of the life of a successful multi-institution ERC, requiring regular review and interactive discussion among various groups of participant institutions. The review process should be balanced to include various Center stakeholders and adequate time for information gathering. Implementing checks and balances to preserve the integrity of the process and minimize stakeholder bias is necessary, yet the process must be simple enough to be practical in terms of time, implementation, and procedural requirements. As the ERC reaches maturity and approaches graduation, less fluidity will be required; hence even the review process itself is not set in stone and should be adapted to the phases an ERC goes through during its life cycle. It is essential that at all stages institutional representatives should act and advise in a Center mode with no bias and no parochialism. Within the established review procedure, the Director’s role as the ultimate arbiter is crucial, and therefore her objectivity and judgment should be beyond reproach.

9.4.2.2 Research Program Refinement or Redefinition

The Center Director is crucial to continuous refinement or redefinition of the research program’s scope in consultation with research thrust leaders and the Scientific and Industrial Advisory Boards (SAB and IAB). It works best if the selection process is neither entirely bottom-up nor top-down but is highly consultative, with the Center Director as the ultimate decision maker.

Technical leadership and researchers among all partner universities first prioritize research needs and review available program resources in consultation with the IAB and thrust leaders. Although advisory groups provide input to the selection process, Center Directors must be careful to moderate the advisory roles so that special interests do not dictate the Center’s research plan to the point that core research becomes fragmented or loses its systems focus. Pressure to support projects that are needed by industry or purported to be needed by industry, within the Center’s core research program, should be resisted. Core research is generic in nature and applicable to a wide range of stakeholders, and should not be in service to narrow stakeholder interests. The outcomes of all group discussions regarding research directions should be communicated to the Director in a concise form. The Director may selectively use or disseminate the information in accordance with ongoing consultation with advisory boards or research leaders. In the case of a substantial change in scope, the Center’s Governing Board or Leadership Team (if one exists and is different from the IAB) should be involved, offering assistance in composing a revised plan. Failure to keep the Governing Board involved in these processes may result in a lack of commitment from partner institutions, a result that carries a substantial threat to the potential 10-year life of a successful multi-institution Center.

9.4.2.3 Revised Thrust-Level Program

The Center Director approves a revised thrust-level research program plan developed by the Research Director and the Thrust Leaders. This plan includes consideration of related Center objectives (such as education, industrial collaboration, and inter-institutional interactions).

The Center Director can use the input received from the thrust leaders and advisory boards to formulate a proposed preliminary

plan and allocation of funds by thrust/program area. This proposal should include consideration for promoting interdisciplinary and intra-institutional collaboration. The Director's thrust/program allocation proposal may then be submitted to the Center Executive Committee, Governing Board, or Leadership Team for evaluation and recommendation. The Center Director is ultimately responsible for defining the research priorities.

9.4.2.4 Project Proposals

Once the scope is defined for an annual funding period, a request for project proposals may be issued, setting forth timetables and deliverables schedules. Potential awardees may then submit project proposals to the respective thrust/program leaders. The thrust leaders may then enlist assistance from industry champions from the IAB in the review, prioritization, and recommendations for project funding, using the approved research plan and preliminary allocation proposal as a basis for discussions. (This is one common procedure. Other mechanisms may be followed.)

9.4.2.5 Project Approval

The Center Director makes the final determination regarding project approval and distribution of resources. In the procedure described above, the Director considers the recommendations of the thrust/program leaders and renders a recommended allocation for incorporation in the final funding allocations. Individual partner institutions may receive more or less than the initial proposal plan sets forth, depending on annual review of assessed progress, future needs, available funds, and the state-of-the-art in the field. Indeed, termination of all projects at a partner institution, if done for clear and identifiable reasons, is legitimate; this allows for new alliances to be established that serve the evolving Center mission. The Director may tap into any or all of the resources available to him/her to facilitate funding decisions.

Partner institutions should be reminded regularly that evolution of the research plan and assessed progress on core initiatives as part of that plan determine continued funding through the Center, which therefore may or may not correspond to the initial multi-year proposal plan. An inwardly focused approach to research challenges and related allocation of resources can threaten an otherwise productive intellectual collaboration. Acknowledgment of this fundamental axiom is necessary to maintain cohesiveness in a multi-institution Center.

9.4.2.6 Continuing Funding

Continued funding for each project is reviewed each year, based on the prior year's progress and the merit of the proposal for the next year.

The Director's top priority in funding decisions is the overall Center health and progress toward long-term goals. Individual institutions are assured of financial support only to the degree that it will be commensurate with the contribution of its Center participants to the overall success of the core program. All communications, calls for proposals, and effort evaluations should reinforce this approach so that administrations for individual partner institutions do not lose sight of the competitive approach to the dissemination of core funds and the continuing need for innovative thinking and approaches to the research.

9.4.3 Research Team Integration

To obtain the benefits derived from an ERC, it is important to integrate the research throughout the organization and achieve collaboration. The collective capabilities and facilities of the Center are more powerful than the individual partners but there must be an organizing principle to achieve the greater capability. A framework to guide the research, points of contact for each activity, good communication within the collaboration, measurable and deliverable objectives, and a certain flexibility to accommodate differences in style are required.

9.4.3.1 Research Integration

Identifying a specific need/purpose for research integration is essential.

Simply obtaining agreement that collaboration is a good idea is not sufficient to bring collaborators from multiple institutions and industries together to actually accomplish the integration of technology. A specific technological advantage to be gained through multi-institutional involvement must be identified in advance of establishing a multi-institution Center. The same

principle applies to a renewed Center, where new alliances replace existing ones in the service of the evolving systems vision. Specific methods for achieving integration should be written, along with role assignment for each of the participating institutions. Projects and their integration should be viewed as Center-wide activities, not as institutional activities.

9.4.3.2 Research Program Structure

Structuring a research program that is interdisciplinary in nature and focused on one or more engineered systems is an effective way to promote ERC culture and is necessary to achieve its goals.

As a matter of course, research faculty focus on their chosen discipline. But the expansion of knowledge in ERC systems-based fields requires reaching beyond the chosen discipline, seeking potentials to link and discover beyond known and established boundaries. Connections are made through communication, and initiation is the key. All ERC participants share responsibility for initiating and cultivating interdisciplinary partnerships. A suggested approach is to engage related disciplines in the proposed ERC undertaking early, possibly through a symposium or information gathering that provides an opportunity for other disciplines to be briefed at a summary level and to offer feedback related to the potential for interaction with the ERC plan.

9.4.3.3 Research Capabilities and Facilities

Institutional partner capabilities and facilities pertinent to achievement of the vision, mission, and goals of the Center must be clearly identified and recognized.

As individuals come together to form a Center, participating faculty usually have or gain a general knowledge of the capabilities and facilities of each of the individuals involved. It is important to expand that knowledge to include the specific facilities and capabilities available to the Center and to include potentially related areas as well, as the idea is to broaden the involvement of disciplines, individuals, and technologies in order to explore new paradigms, thus achieving what could not have been achieved without the Center. Education is closely related to research; hence the research plan also provides the basis for the Center's education plan from which uniquely trained individuals emerge.

9.4.3.4 Framework to Guide the Research Process

Roadmaps, testbeds, and benchmarking are essential management tools for integrating faculty research and assessing progress.

Routine communication can be bogged down in individual preferences for certain research aspects, constraining productive use of time and minimizing overall progress. It is advisable to establish a framework to guide the process and assess progress toward meeting Center goals. One of the most effective means of integrating research and determining the criticality of individual projects is capstone projects or testbed applications. Testbeds should be end-to-end applications that bring together many or even all of the tools and knowledge, not *in* a thrust but *across* the thrusts. Planning for testbed applications exposes projects that are not germane to the Center mission.

9.4.3.5 Point of Contact

A central contact should be established for each area of activity.

Communication with the individual best suited to respond is as important as communicating regularly and effectively. Individuals responsible for specific roles and or target areas should be identified and contact information centrally distributed so that communications are direct and channeled appropriately. This is part of the complete management plan of the Center, which should be agreed upon and available to all involved. No activity should be left without a responsible contact individual.

9.4.3.6 Communication is Essential

Frequent and direct group communication is essential to success.

Because there is a growing emphasis on outreach in all Centers, this demands an increased awareness of the need for continuous and effective communication. Communication provides the basis for all actions, interactions, and decision-making in the Center environment. A suggested approach is to establish (as a minimum) a schedule for regular interaction/collaboration of each thrust group, project group, the industry board, the Executive Committee, and each of the advisory boards. Additionally, each partner institution should establish a regular on-site meeting devoted solely to ERC

business. This is desirable because Center activities are often a subset of the activities of individual participants. A scheduled meeting forces focus on the activities specifically related to the ERC. Many other opportunities will evolve with the needs of the Center and should be encouraged by senior management. In addition to project, thrust and board integration, it is essential that cross-cutting interactions are instituted in the ERC, whereby 'horizontal groups' cutting across the thrusts meet face-to-face or virtually, and focus on threads that link across thrusts toward Center objectives.

9.4.3.7 Program Measurables: Statement of Work and Period of Performance

Specific task assignments such as Statements of Work (SOWs) and Periods of Performance (POPs) should be established.

Regular monitoring, reporting, and sharing of project progress is especially important in a multi-institution Center due to the geographic dispersion of the participants and the consequently limited ability to observe progress directly. The annual call for proposals, where used, will be most effective in an atmosphere where effort assignments and SOWs for the review period are clearly defined, disseminated, and reinforced through discussion. All projects should have project sheets that articulate milestones and deliverables that are further linked and integrated at the thrust and system levels. Annual coordination of meetings and meetings prior to or after site visits are ideal forums for assessing progress and re-charting the Center's path.

9.4.3.8 Opportunities for New Faculty

Opportunities for new/junior faculty should be apparent.

The expanded opportunity inherent in on-site Center management support is often diluted by the geographic dispersion of the partners and the Center profile may differ among partner institutions. Extra effort may be necessary to ensure that a new/junior faculty member is fully aware of the research underway and the ways in which he may become involved. It is important to train at all levels, including junior faculty, so that the Center will have a lasting influence on the research culture, away from unsolicited proposals and towards the Center's ethos.

9.4.3.9 Industry Research Champions

Engage industry partners to serve as research champions and testbed partners as well as mentors and technology transfer participants.

Collaboration with industry should and will occur in many different ways, especially in the multi-institution environment. It is essential to engage industry in such a way that the flow of ideas, information, and results is continuous and timely. One way to be sure that the Center is receiving and responding to industry interests is to engage industry members as research champions. A research champion serves as a mentor in a particular aspect of development and works closely with Center Thrust Leaders to ensure industry relevance and facilitate direct knowledge transfer. Industrial participants also greatly enhance the educational experience by serving as mentors to young faculty and students; the guidance they provide encompasses research, career choices, and industrial interaction. This model has been very effective at many Centers, enhancing the level, continuity, and quality of industry involvement.

9.4.3.10 Failures Can Occur—Know When to Cut Losses

There is no failsafe mechanism to ensure that all actions, decisions, plans, and policy implementations will result in a model, integrated, multi-institution, productive research undertaking. Incremental failures will almost certainly occur. A plan for acknowledging failure and moving forward in spite of it, while addressing the shortcoming, should be in place. The Center Director and its leadership should not shy away from taking bold decisions.

9.4.4 Role of Testbeds

The boundaries of the knowledge fields addressed by ERCs are virtually unknown. Testbeds provide a means of demonstrating potential and inspiring intellectual exploration beyond the knowledge proven through demonstration.

As the product of the Center's collaboration, testbeds provide a basis for the assessment of research outcomes, a means for integration of research, and a way to demonstrate systems' impact. They are the focal point for collaboration and guide the

investigations by offering greater understanding of the issues. They drive modifications to the strategic plan and are the basis for knowledge transfer.

9.4.4.1 Focus for Integration

Testbeds provide a focal point for researchers to rally around and pursue common goals.

A testbed provides a conceptual framework and a tangible way to demonstrate the integration feasibility of a particular tool set. It can be a catalyst for excitement among researchers as well as provide a shared vision for continuing exploration. It also yields results of interest to those supporting the Center; so it is useful—not just a showcase.

CASE STUDY: *At the MAECenter, testbeds apply the various tools to a system (transportation networks), a region (city or state) or an organization (national or state emergency management agency). They integrate all products of the projects and thrusts to provide a scenario of the possible consequences of an earthquake on the testbed system, region, or organization.*

9.4.4.2 Improved Understanding

Testbeds provide a basis for better understanding of system requirements and barriers.

The visual realization provided by a testbed demonstration may serve as a teaching device for researchers not previously immersed in the concept demonstrated. Concept edification through proof is an effective and powerful tool. In a multi-institution, multi-disciplinary, multi-sponsor environment, demonstration can be the difference between discovery and incremental advances.

9.4.4.3 Driver for Continuing Research

The “proof of concept” achieved through testbeds nearly always serves as a driver for continuing research. The exploration of true knowledge synergy or the compatibility of traditionally separate application areas is enhanced through testbed applications in the context of multidisciplinary cooperation.

The revelations resulting from testbed demonstrations have the potential to turn a skeptic into an advocate or, conversely, terminate exploration along a less-than-promising course. In either case, knowledge is gained and further exploration is seeded. Integration of subsystems, disciplines, and concepts tends to have a unifying effect on the individual researchers involved, spurring broader contemplation and intellectual discussions.

CASE STUDY: *Currently, there is relatively limited understanding of the dynamic behavior of power electronics systems or of how the systems may be modeled and controlled. Testbed demonstration of the fundamental nature of system-level issues at CPES is expected to open new opportunities for expanded use of advanced electronic power distribution systems.*

9.4.4.4 Driver of Modifications to Research Plan

Ultimately, testbeds may drive modifications to the strategic research plan based on the learning achieved through systems analysis and test results.

One of the bonuses of unplanned discovery is the alternative path(s) presented to the researcher. In the case of a multi-institutional, multidisciplinary Center, the intellectual consideration spurred by an unplanned discovery is often exponentially increased. This may lead to a stronger strategic plan or a modification to the original plan that strengthens the original concept. Many centers set aside “seed” funds to nurture such discoveries.

9.4.4.5 Industry Knowledge Transfer

Testbeds provide a strong basis for the continuing exchanges and knowledge transfers with industry. Through this vehicle, Center research remains pertinent to industry and provides a platform for it to create products or develop technologies.

Historically, testbed demonstrations are well-received by industry; industry representatives typically provide useful feedback stemming from testbed demonstrations. The Center can use this feedback to enhance research and produce additional useful

results for industry application. This sharing also complements the dissemination of information that is the common mission for universities and ERC.

9.5 EDUCATION PROGRAM MANAGEMENT

Multi-institution Engineering Research Centers face special challenges in organizing, planning, and administering their education programs. Despite the added complexity, however, a multi-institution Center offers many unique benefits, including opportunities for students to take a wider variety of courses or work on research in more than one university. These students can be exposed to a broader spectrum of research.

9.5.1 Challenges

A fundamental challenge that ERC Education Directors need to address at the outset of the Center is determining the best organizational structure for implementing the multi-campus education program. Early on, the Center management team holds strategic planning sessions to determine the mission and goals for their education program. They then develop a plan, staffing, schedule, and budget to accomplish these goals. Issues to be addressed include:

- What resources (faculty, staff, and infrastructure) are available on different campuses?
- How can multi-campus education committees best be formed?
- Who should be on the committees?
- Will administrative staff be available on each campus?
- Will management of the education program be centralized or distributed?
- Will inter-institutional agreements be necessary?

As a multi-campus Center begins offering education and outreach programs, such as a Research Experience for Undergraduates (REU), Research Experience for Teachers (RET), outreach programs for precollege teachers and students, Student Leadership Councils (SLC), student exchanges and seminars, the best ways to administer these programs will need to be determined. Questions such as these must be addressed:

- Which campuses will participate?
- Who will coordinate each of these efforts?
- What resources are available?
- How will recruiting for the outreach programs be coordinated?
- Which principal investigators will host students and teachers?
- Where will seminars be held?
- How will communication between participants on the different campuses be facilitated?
- How can video, teleconferences, and the web be best used to promote communication?

As the multi-campus Center develops new courses, course materials, certificates, and degree programs, ways for students on all Center campuses to take advantage of these offerings will need to be arranged. Inter-institutional agreements on credits and fees may require authorization. Mechanisms to offer distance and web courses as well as jointly taught courses may need to be developed.

Similarly, offering multi-institutional continuing education short courses to industry presents challenges. Short courses may be offered either for degree credit or continuing education units (CEU). Mechanisms for receiving credit at different schools and sharing revenues need to be worked out. With Industrial Advisory Board (IAB) input, course topics and instructors will need to be established, as well as mechanisms for delivery (short course, web, or distance course). Finally, the sponsoring university(s) needs to be ascertained. Alternatively, a Center can offer a non-credit short course without any sponsoring university. Subcontracts may be needed to pay speakers, and mechanisms for sharing advertising and administrative costs will need to be determined.

For the secondary-school level and community outreach, strategies for instituting partnerships with schools and organizations in the different communities need to be developed. For example, Center staff can partner with other outreach programs at their university; professional organizations offering precollege outreach, or member-company outreach efforts in various communities. Decisions will need to be made about which campuses can best initiate outreach programs, administer funds, coordinate activities, and provide oversight. For recruiting purposes, partnerships with various minority-serving institutions in different locations can help the Center achieve diversity goals. Here again, decisions about which Center universities, and who at each university, will initiate these partnerships will need to be made.

The following sections will discuss in more detail the challenges and opportunities for multi-institution Centers in:

- organizational structure and strategic planning (5.2)
- developing new curriculum, degrees, and certificates (5.3)
- managing special programs for students (5.4)
- outreach to industry (5.5)
- facilitating collaborations and partnerships with schools and community organizations (5.6).

Each section will also summarize some of the lessons learned in developing multi- institution ERC education programs and illustrate the best practices using case studies.

9.5.2 Organizational Structures and Strategic Planning: Education Director’s Role

9.5.2.1 Central vs. Distributed Management

It is important to build a network of communication and an atmosphere of cooperation among participating faculty and universities to address the Center’s research and education missions. A common understanding of respective academic procedures must be built so that obstacles to carrying out specific Center-based educational activities can be minimized. This is particularly true for curriculum development activities, which may require departmental approval for a program created by non-host institution faculty. These issues can arise even within a university, if a Center wishes to implement cross-disciplinary courses or modules involving other than engineering disciplines. Regardless of these barriers, inter-institutional, cross-disciplinary knowledge and technology transfer remain a significant element of the National Science Foundation’s mission for the ERC program. It is important for Education Directors to involve their Center Directors in exploring avenues to successfully address these issues.

Finding an ideal approach to surmount administrative obstacles can be very time-consuming and may result in an undesirable lag in transferring timely and valuable knowledge derived from research endeavors to students and other potential end-users. If such delays appear likely, it may be that this knowledge can be more effectively communicated by integrating it into existing credit-bearing courses, with CEUs or independent study programs as alternative solutions. It is important to maintain a robust interface between research, education, and the end-user community.

The Education Director may well serve the Center’s interests by working with each institution to learn about the structure of course administration, so as to better understand which issues might keep ERC education exchanges between universities from becoming a reality. As educational products are developed, these constraints and ways to address them may be kept at the forefront of consideration.

Remote learning opportunities also have burgeoned in the past decade, making access increasingly easy, affordable, and convenient, and bypassing some of the usual institutional constraints. At the same time, these efforts require oversight and maintenance and must address necessary education standards (whether academic or professional), if credits of any kind are to be awarded. Furthermore, credits earned through online learning programs are not always given equal weight within the discipline or profession.

Overall, it is necessary for the Center Director and Education Director to establish leading guidance and give encouragement to program advocates at each participating university. Without this advocacy and support, extra-institutional commitment to Center-wide programs is not likely to occur and outcomes are less likely to be realized. A Center-based Education Director (with support of the Center Director) can be an important catalyst by establishing proposed activities, budget limits, desired outcomes, and standards, which can be endorsed and promoted to the other institutional participants. The Center Director can provide further incentive by emphasizing to faculty the relative weight of education within the overall Center program.

Willingness to advance the education objectives of the Center will then be viewed as having a bearing on funding decisions regarding individual investigators.

On an administrative level, it can be very difficult to extend financial support to other institutions in a timely way, including student stipends, travel funds, etc. This can be an impediment to accomplishing desired tasks, and is an area where Centers can learn and benefit from each others' experiences to improve the funds-exchange mechanisms. For multi-institution Centers, relinquishing funds to other institutions may mean losing control over use of those funds, selection of activities, recruitment of students, etc. In spite of bureaucratic headaches associated with Center management of distributed education funds, it does allow the Center to remain true to its objectives and standards. Center representation at major education functions should involve all participating institutions, yet should always reflect the central vision and leadership.

9.5.2.2 Negotiating Inter-institutional Agreements

Formalized agreements allow Centers to predetermine desired educational goals and outcomes. It may be very difficult for institutions to agree to exchange curricular products as a requirement of their subcontracting agreement. Institutional agreements may instead take the form of something less legally binding, while still demonstrating a mutual agreement between institutions to work toward a common education agenda. A memorandum of understanding may help to achieve this, with clearly stated goals, desired outcomes, and timetable for execution

9.5.2.3 Forming and Using Multi-campus Committees

Some Centers have established multi-institutional committees to direct and achieve their education goals. Often, teaching, research, departmental obligations, and other functions interfere with the faculty participants' dedication to the multi-campus committee activities. It is often necessary for involved faculty to seek released time or other benefits from their institution to devote sufficient time to education committee activities. This will bring an added benefit to the Center, however, as a demonstration of cost sharing.

It is also extremely important for the faculty members to be able to devote their efforts on behalf of the Center, over and above their own individual professional efforts. There must be an exhibited level of commitment to the education vision and mission for this participation to be of optimum value to the Center's education program. In addition, for multi-campus committees, there must be regular interaction (monthly, at minimum) to assure continuity of communication. This is essential to sustain momentum of the activities planned, particularly in view of the continual turnover of participating students and changing demands on faculty. The latter is particularly true for tenure-track faculty.

Rotation of committee members helps infuse enthusiasm. Retaining some long-term members helps to assure that momentum is maintained. The ability of committee members to rely on administrative support and assistance from Center headquarters is also helpful.

If these difficulties can be overcome, a multi-institutional education committee can truly enrich the education experience for those involved. Institutional support and faculty commitment are necessary ingredients in the success of this framework.

9.5.2.4 Setting Program Goals and Objectives

Center program goals are based on the leadership team's determination of its vision and mission, its anticipated outcomes, and the resources (both human and financial) at its disposal. Both goals and objectives need to be shared with all faculty and NSF Program Officers, iterating the process until general consensus is reached on future activities.

9.5.2.5 Allocating Resources

The Center must have clearly defined education activities, objectives, and outcomes when allocating resources. For a multi-institutional activity, the Center must give extensive consideration to fiscal regulations and procedures at its institutions. Unexpected indirect cost recovery, misallocation of costs incurred, and other fees associated with administrative management or education program conduct (e.g., charges for facilities for video/tele/communication activities) can place an unexpected drain on Center funds. A yearly plan that outlines desired activities, costed out at participating institutions, can help to anticipate financial difficulties. While there will always be unanticipated costs, it is incumbent on education leadership to develop an understanding of probable costs and operational issues that may impact the conduct of the program.

Funding of students for special activities such as conferences and study tours is best decided based on a predetermined level of

academic standards and expectations. The Center should try to encourage participating institutions to have input into setting benchmarks for spending on various activities, with ultimate decisions to be made by the Center Director and the Education Director.

9.5.2.6 Identify Center Activities

Center-sponsored courses and outreach activities all need to be clearly marked with the Center logo and attributed to the Center, as well as to each of the participating universities. Any press releases issued should also clearly identify the activities as Center sponsored.

***CASE STUDY:* Multi-institutional Education Committees.** *The education program at the Pacific Earthquake Engineering Research (PEER) Center is designed to introduce, stimulate, cultivate, and educate undergraduate and graduate students with the knowledge that will enable them to contribute to the earthquake engineering profession from a variety of disciplines and perspectives. PEER's Education Committee, comprised of representatives from all 18 core and affiliated universities, is charged with the planning and implementation of the Education Program.*

9.5.3 Developing New Course Curricula and Degrees

Development of new curricula, degree, and certificate programs may be a key output for an ERC, and one of the means by which a Center creates a legacy. Examining core research area curricula, during the proposal and early award, will establish baseline information for the Center's operations and identify strategic planning issues that may be important to intercampus collaboration. This section provides ideas and recommendations for developing new courses; for creating new programs out of these new courses; and for implementing, tracking, and disseminating information relative to this component of the Center's work. Subsections include specific examples pertaining to distance learning, web courses, team teaching, and inter-institution agreements relating to these.

New course development in a Center is a single variable within the larger context of curriculum development, course revision, new course module development, and new program development. Innovations and modifications within individual curricula also provide Centers with a means of addressing their goals within the ERC, such as: promoting visibility of key disciplines within undergraduate and secondary school communities; providing critical resources for industry; and building interdisciplinary bridges within a department and college structures of a university. In addition, multi-campus Centers are organized in order to bring together institutions with diverse strengths, often pairing programs with long histories of contributions to core disciplines and technologies with emerging programs. Consequently, the very organizational structure of the ERC may dictate that the approach to curricular issues be considered at both a campus level and a Center level. Therefore, early consideration of the following key questions should prove useful in the strategic planning phase of education program development.

1. *Creating a common frame of reference for existing courses:*

   - Which courses at each institution form the support structure for the core and associated research areas? Create a reference document with appropriate supporting material that aggregates this information for all partner campuses.
   - Among these courses, which ones are suitable for intercampus cross-listing for student exchange and distance learning purposes?
   - Among these courses, which are currently in distance format? This information should be publicly accessible to students and industry. Course descriptions, registration, deadlines, and contact information should be posted on the Center's web site and updated regularly.

2. *Planning curriculum development:*

   - Based on the Center's research goals and areas of expertise, which courses should receive the highest priority for conversion to distance format? Based on the evolution of the Center's research program over time, research advances in the field, and emerging areas of expertise, this question should be revisited throughout the ERC award period and the strategic plan modified as appropriate.

- What new courses should result from the Center's core research mission and areas of expertise?
- Which existing courses should be modified to include the ERC's latest research results?
- Will the creation of new textbooks (or chapters for existing textbooks) be a priority for the education program development effort? To what extent will this reflect the multi-institutional nature of the research effort?
- Will curricular development extend to the precollege level? If so, have appropriate relationships been established with precollege teachers and other STEM (science, technology, engineering, and mathematics) educators and experts? Will test beds or pilot programs be developed as part of this effort?

3. *Developing new courses within the framework of ERC goals:*

- How does new course development reflect the interdisciplinary nature of the ERC's research?
- How are courses distributed across undergraduate and graduate levels, both within individual institutions and within the Center as a whole? How will new course development support both the need to involve more undergraduates in the Center's core research area and the needs of graduate students who will be working in emerging, interdisciplinary, or nontraditional research areas?
- Will new course modules be developed in support of the ERC's student recruitment and information dissemination priorities? If so, who is the target audience, which concepts are key for presentation, and at what academic levels should they be presented? Which campuses are best suited to undertake the development work? How will this information be disseminated?
- What resources will be needed to support new course development and implementation? What resources will be allocated through the Center's core award for these efforts? How will funding decisions be made? What external sources can be sought for support of these initiatives? To what extent do new courses depend on new facilities/infrastructure within the Center?
- How will the needs of the Center's industrial collaboration program be served through course development? How will needs in this area be determined and addressed?
- How can the collaborative nature of the ERC's research program, as well as the expertise of key faculty and thrust leaders, be cultivated through its education program? Will courses team taught by faculty across partner campuses be a goal?

4. *Addressing the needs of each core partner institution:*

- Do any of the Center's core partner institutions lack key courses that are needed for them to become fully engaged in the research effort? If so, how will this be addressed?
- When reviewing the Center's core curricula from an intercampus perspective, are any course articulation issues apparent? If so, how will these issues be addressed for successful implementation of distance learning and exchange programs?

5. *Repurposing materials to serve constituents:*

- How will the products of curriculum development efforts (courses, modules, etc.) be leveraged? Can sections of new courses be retooled and restructured to form new short courses for industry? Will new course modules be implemented across campuses? Should existing modules be retooled for implementation in different courses?

6. *Developing new programs:*

- How should new and planned courses aggregate to form new programs for options, certificates, and degree programs as well as short courses and workshops?
- How will new certificate, option, and degree programs be distributed across academic levels and Center constituents (precollege, undergraduate, graduate, postdoctoral, and industry)?
- What buy-in is needed from departments, colleges, and universities as well as committees (research area, distance learning, graduate, undergraduate, curriculum) located within these administrative structures? For undergraduate engineering courses, how will these courses address ABET requirements?

7. *Implementing new courses and programs:*

- How will new courses and programs be implemented and disseminated? Who will be responsible for each of these tasks?
- How will new course materials be shared throughout the Center's partner institutions? How will this information be shared outside the ERCs? What format will the shared materials take?
- How will the policies and procedures necessary for the sharing of curriculum-based resources across campuses be developed, approved, and implemented?
- What will be the long-term impact of this education program development and how can it be quantified? How will progress be measured relative to the strategic plan? How will success be measured?
- If a program is to be implemented across campuses, must it take the same form at each institution?
- How will the education program leadership ensure that education program results are disseminated through conferences and journal publications?

The Education Director, in consultation with an intercampus Education Committee, should consider the above questions early in the award period. Since curriculum development is linked with the Center's research focus and reflects its interdisciplinary and multi-institutional nature, it is important that the Education Director and the Education Committee reflect this reality throughout its membership and functions.

It is important to note that the success of curriculum development initiatives depends upon a certain level of buy-in from various constituencies within departments, colleges, and universities. In the case of interdisciplinary course and program development, bridges must be built beyond the level of the individual faculty member and articulation among various degree programs (relative to courses and their prerequisites, as well as degree requirements) may also be warranted. For this reason, the Education Director (or other education program representative) must be prepared to devote a significant level of effort to communication, discussion, and strategic planning with these groups. It is essential to ensure that the education program at each campus includes both the faculty and support personnel necessary to advance the Center's efforts, and to maintain and promote new courses and programs once they have been developed. Often, administrators at partner campuses can assist with this function.

Departments often include support personnel such as undergraduate and graduate academic advising staff, outreach coordinators, and/or enrollment services coordinators. Such offices routinely receive feedback from students that can be helpful in strategic planning relative to curriculum. These offices can also help raise student awareness about these new programs.

It is important to recognize that throughout the life of the ERC, curriculum development initiatives and the Education Strategic Plan as a whole are living documents that are influenced by a variety of factors. For example, through the NSF Site Visit, industry and student SWOT processes, additional opportunities and priorities may be identified. Similarly, initiatives such as certificate, concentration, and degree programs established early in the Center's life cycle must be reviewed and updated at regular intervals to include new and modified courses that are developed under Center leadership. An Education Director of a multi-institution ERC can assist in this process by monitoring administrative changes and progress at all campuses at regular intervals and soliciting assistance from campus administrators to follow up on key issues.

It is important to keep the faculty involved in the education program in general and in curriculum development initiatives in particular. It is useful to solicit input directly from research thrust leaders and other key researchers within the Center at regular intervals to discuss progress vs. plans, strategic planning for out-years of the award, and response to SWOT issues. In this way, barriers can be identified and addressed early in the process, and in an environment that takes advantage of relevant multi-campus expertise issues.

CASE STUDY: *At the Center for Power Electronics Systems, a Research Retreat is held on an annual basis for the purposes of long-term strategic planning. Each year, one afternoon and/or evening of the Research Retreat is reserved for an Education and Outreach Program Retreat to which all of the Center's research investigators are invited. This meeting has proved a useful forum for reviewing the work of the Education Committee and soliciting input relative to key implementation issues.*

9.5.3.1 Issues in Offering Distance Learning and Web Courses

Distance learning can serve as an important tool for dissemination of Center expertise and resources to partner institutions, to entities external to the core partners, and to industry. Successful implementation of distance learning programs within the context of an ERC depends upon the degree to which courses have been integrated across campuses and the extent to which students view this knowledge as essential to the research that they are conducting within the Center. It is important to understand the distance-learning component of the Center's education program within the context of its research mission, and

as a resource for emerging programs within its consortium. Further, it is important to identify and prioritize courses to be converted to distance format as a part of new course-development strategic planning.

Since distance learning programs often are institutionalized through departmental and/or college committees, outreach program offices, or special initiatives offices, it is necessary to determine how decisions related to distance learning courses are made within each partner university, how new course development is prioritized within departments and colleges, how resources are allocated, and who will provide leadership within the committee structure of each university in order to champion the Center's programs and objectives.

In some cases, the Education Director or Coordinator may be responsible for organizing intercampus student input relative to the distance learning course development plan, distance delivery modes, and learning objectives. The Education Director or Coordinator may also play a role in coordinating logistics for distance learning courses that involve team teaching across institutions.

Intercampus agreements supporting the distance-learning component of the education program should address issues of registration, advising, required approvals, information dissemination, grade assignments, costs, and credits. Depending upon the nature of individual distance learning programs, some partner campuses may rely more heavily on distance access of courses than others. If this is an underlying issue for an education program, the associated cost considerations should be addressed as part of the Center's cooperative agreement.

CASE STUDIES:

Using Distance Learning as a Tool for New Course Development. *During a strategic planning meeting at the Center for Power Electronics Systems (CPES), it was discovered that one of the partner campuses lacked a key element within its curriculum. The absence of this course was a barrier to full engagement of that partner institution in the Center's research program. A course that addressed this need was identified within the curriculum of the lead institution. Center resources were then devoted to converting this course to distance format, which was then offered exclusively to students at the partner institution. Office hours were also conducted through distance delivery by graduate student mentors at the lead institution. The following year, the faculty responsible for this course at the lead institution shared all course materials, including lecture notes, projects, and homework assignments, with a faculty member at the partner institution. Videos furnished by the lead institution were then used as the basis for offering the lecture component of the course, while recitation sessions were conducted by faculty at the partner institution. During the third year the course was offered, it was customized to better resonate with the curriculum of the partner campus. The course was then conducted entirely on site at the partner institution, after having been approved as a permanent part of the curriculum. This course development, while not originally a part of the Center's curriculum development plan, had an immediate positive impact on the number of students pursuing power electronics at the undergraduate and graduate levels, and led to increased involvement of the partner campus in the Center's research and academic exchange programs.*

Multi-institution Course Credit Agreements. *CPES has established two cooperative agreements that support intercampus collaboration in the Educational Outreach program area. During Year One of the ERC award, CPES established a core course listing in the areas of power electronics, packaging, and systems design and integration. At present, more than 80 power electronics and related courses are available through CPES partner campuses, with credits for these classes accepted by each student's home institution. Twenty-seven of these courses are offered for distance registration. In order to facilitate intercampus course registration, CPES established a Cooperative Agreement for the Distance Access of Courses. This document, signed by officials of each ERC partner institution, establishes a set of common policies and procedures for cross-registration including billing for tuition and fees, payment of incremental costs, recordkeeping, registration, and the terms of distance delivery. The Cooperative Agreement for Exchange of Graduate Students allows Center students access to the portions of the core curriculum that are not offered by distance delivery, while also providing them access to the research facilities at each of the partner institutions. The goal of this agreement is to exploit the diverse technical strengths of each of the Center universities by developing uniform policies and procedures regarding student exchange among the core partner institutions. As part of this agreement, CPES partner universities established policies pertaining to tuition, billing, registration, course curriculum, and reporting of annual statistics to NSF.*

9.5.3.2 Team Teaching Courses in a Multi-Institutional Environment

While distance learning courses shared among campuses can be a useful mechanism for creating synergy within the Center, many are often taught by a single instructor. Multi-institution ERCs provide significant opportunities to expand this model of sharing expertise across institutional boundaries. In some Centers, significant benefits have been derived from introducing

team teaching into the ERC's strategic plan for new course development. Models may include new courses, which cross the boundaries of a single departmental and/or discipline; or new courses, taught in distance format, which involve instructors at one or more partner institutions. In the latter case, the Education Director or Coordinator may play a significant role in coordinating the planning, development, and implementation of these courses, and in soliciting feedback in a multi-institutional format.

CASE STUDY: ***Team Teaching as a Method of Disseminating the ERC Research Vision.*** *The course* Power Electronics System Integration (PESI) *is team taught by professors at all CPES campuses, and serves students at each of the five partner campuses. This one-credit seminar course is required for all Center students. The course serves to communicate and reinforce the Center's research vision to upper-level undergraduate and new graduate students. This course involves lectures and intercampus discussion sessions related to the Center vision and each research thrust area. Lectures include introductions to new research foci and breakthroughs, and linkages among CPES research thrust areas. All course materials are freely available on the Center's web site and are revised annually to reflect new research developments as well as the evolution of the Center's research program.*

9.5.4 Cross-institutional Student Opportunities and Organizations

Students in a multi-institution ERC have a somewhat different experience than students in a single-university ERC. For example, the Student Leadership Council at a multi-institution ERC often is composed of students from all of the universities, and students have the opportunity to participate in exchanges with partner institutions. Students are exposed to partner university faculty through distance learning and team teaching, so students graduating from one partner university often go to another partner because they are known and the institutions have similar academic and research foci. The programs and events of the ERC-education, research, symposia, and Site Visit—bring the students from the partner universities in contact with other students, professors, industry professionals, and NSF professionals. The SLC needs a budget to carry out its duties.

9.5.4.1 Multi-institutional Student Internships and Student Exchange Programs

Internships can be very valuable. A central coordinator and budget manager with administrative contacts at participating institutions can help make the educational experience shine. Grant administration of funds to support student internships and exchanges at multiple institutions may vary widely. While a stipend might work at one institution, it might be unacceptable at another. The Education Coordinator needs to explore a wide range of mechanisms that can be employed to support student exchange programs and ensure their success.

9.5.4.2 Multi-institutional Student Leadership Council (SLC)

Students at multi-institution ERCs meet and interact with their peers from partner institutions periodically throughout the year. These meetings may coincide with other ERC activities, such as an annual research colloquium, site visits, the NSF Annual Meeting, etc. Prominent annual technical meetings associated with the field also offer opportunities for the students to meet and work together. Videoconferencing is also very popular, as are web-based communication tools such as Net Meeting. An accurate and up-to-date e-mail listserve helps to mediate communication issues that can arise because of geographical separation. Newsletters and SLC websites also provide a forum for participants.

Recruiting students into the SLC can be problematic. It is imperative that, in addition to the Education Director, an enthusiastic faculty member at each institution champion student participation in the SLC.

9.5.4.3 Recruiting Across Partner Institutions

Regular interaction among members of the Center research teams is instrumental in promoting involvement and recognition of participating students. This may open doors for students to seek professional opportunities at other Center-affiliated institutions. Center management should encourage this exchange, particularly for the matriculating student.

CASE STUDIES:
SLC Exchange Program. *As a five-university research Center, CPES has been challenged to develop innovative programs supporting a culture of exchange among faculty and students. CPES students have identified novel approaches to traditional programs in order to achieve this goal. In 2002, CPES established Research Experiences for Undergraduates (REU) programs at Virginia Tech (VT) and the University of Puerto Rico-Mayagüez (UPRM).*

This program complements an existing student-developed initiative to provide short-term exchange opportunities to undergraduate and graduate students interested in performing collaborative work in power electronics. Through the short-term exchange program, CPES is able to invite graduate students for a parallel eight-week summer research experience. During the past two years, CPES has hosted REU and graduate exchange students from the same home campuses, providing undergraduate students who are new to CPES and power electronics with experienced mentors from their home campus as well as the VT campus. The pairing of these two programs has also allowed the Center to maintain closer contact with program participants over time, and has provided opportunities to create a support system for participating students to continue their research after they return to their home campus. Summer exchange students are encouraged to continue their collaboration with host institutions by completing follow-on work through short-term exchange experiences throughout the academic year. Students who have completed undergraduate research exchanges are welcomed back as graduate student mentors in subsequent years. In some cases, students who have been recruited by the host institution for advanced degree work serve as mentors for undergraduates from their former institution. CPES sponsors more than 30 short-term exchanges annually, more than half of which involve underrepresented Hispanic or African-American students.

***Weekly Research Teleseminars**. The ERC for Environmentally Benign Semiconductor Manufacturing uses weekly teleseminars to update students, PIs, and industrial partners on the current progress of research projects. These teleseminars are an effective tool used to give industry members access to research developments as they occur. The seminars follow a simple but effective format: Visual presentation materials are posted weekly on the Center's website for download in advance. This gives all participants the opportunity to view the presentation materials in advance. At the time of the presentation, Center members, industrial advisors, PIs, and students dial in to the teleconference from their desks or conference rooms. In a typical one-hour teleconference presentation, a short discussion on one of the active research projects is presented. Instant feedback is obtained from the industry partners and other Center researchers, and all are kept abreast of the status of current research activities. This series is very well received and is an excellent tool for rapid information dissemination to industrial mentors and advisory boards. It is also an excellent means of communication within the Center. Students are involved in the teleconferences. They are given the opportunity to invite and coordinate speakers, present research results, and lead discussions on specific activities, as well as hear the results of the Center's research. This same teleconference format has been used for discussion of other ERC activities and Center-wide planning and discussions. Typically, 40 to 45 teleseminars are held annually.*

***Multi-Campus REUs.** Because their REU students were located at multiple institutions, the Earthquake ERCs—the Mid-America Earthquake (MAE) Center, the PacificEarthquakeEngineeringCenter (PEER), and theMultidisciplinaryCenter for Earthquake Engineering Research (MCEER)—initially encountered some challenges in implementing REU programs. They have since overcome those difficulties and even learned to cooperate among themselves very successfully in this area. The ready availability of videoconferencing has been very helpful in this regard, along with a multi-Center REU symposium at the end of the summer. Some of the REU activities have led to closer collaboration between graduate students and faculty members. Since their inception, the three ERCs have had many such tri-center projects. While each Center has an REU on its diversified campuses, there is a combined REU symposium for all participants. The three Centers take turns in putting this on. The Centers develop and then share graduate teaching modules on specialized subjects.*

- ***Networking Multi-institution Centers.** Researchers at MCEER, at the University of Buffalo, are leading the initiative to create an electronic network linking its diverse experimental facilities. The object is to overcome geographic limitations and leverage the existing capabilities to share experimental and advanced computational resources and data. The establishment of the network requires developing new procedures and methods, adapting and integrating existing technologies, and developing new methods of communication, storage, and interpretation.*
- ***Graduate Student Exchange Program.** Virginia Tech's CPES students majoring in electrical engineering may attend classes at all five CPES universities, with credits for classes accepted by each student's home institution. The goal of this program is to provide students with a broader background and allow them to take courses not offered at their home institution. It is designed to maximize interactions among graduate students, provide opportunities for students to experience different learning environments, and expose masters-level students from one of the campuses to the possibilities of pursuing a PhD at another campus. It has been necessary to devise collaborative agreements to set forth the policies and procedures governing cross-university programs and student exchanges.*

***Joint ERC Student Activity:** In 2002, PEER initiated a tri-center Earthquake Field Study program. Four graduate research assistants from each Center plus four non-Center graduate students (selected by professional earthquake engineering organizations) compete to spend ten days visiting a recent earthquake site in order to engage in a*

hands-on field assessment exercise. Each Center may send one advisor to accompany the student team. Funds to cover round-trip travel, participation in the week-long field trip, food, and lodging are provided and industry fellowships are encouraged.

In October 2003, thirteen graduate students, two professors, and a staff member traveled to Italy for a week-long study and tour of earthquake laboratories and field sites. The students were sponsored by the three earthquake centers: MCEER, PEER, and the MAECenter. The mission was organized by MCEER. The trip began with visits to laboratories in the area surrounding Milan. Site visits included the Joint Research Centre's European Laboratory for Structural Assessment (ELSA) at Ispra, University of Pavia, University of Rome, La Sapienza, University of L'Aquila, the devastated village of San Giuliano di Puglia, and Naples.

After their return to the U.S., the students were asked to make at least two presentations during 2003-04 based on what they learned during the trip. One presentation was directed at students or adults without an academic background in engineering or earthquakes—for example, upper-grade high school students or lower-division undergraduate students. The second presentation was a technical seminar for graduate students and professors at the earthquake Centers.

9.5.5 Outreach to Industry

Offering multi-institutional Continuing Education Unit short courses for industry can be challenging. The focus of initial planning is on prospective topics and industrial interest (with IAB input, possibly through a market survey), potential instructors, and mechanisms for delivery (short course, web, or distance course). The originating university(s) needs to be decided. Mechanisms for receiving credit at different schools (academic credit or CEUs) need to be arranged. Or a Center can simply offer a non-credit short course. Mechanisms for sharing advertising and administrative costs as well as formulas for sharing revenues may need to be determined. Procedures to pay the speakers both from industry and universities may need to be established.

9.5.5.1 Planning the Course

Certain questions can arise in the planning process: should the industrial courses be a push (i.e., the ERC wants to offer a course) or a pull (i.e., industry requests a course) activity? Are the administrative and financial resources available for planning and teaching a course? Will the Education Director and/or Coordinator plan the courses using Center administrative resources, or will the activity be decentralized to the course champions at different universities?

Determining course objectives and target markets is very important prior to offering any courses for industry. This may involve adopting a private-sector mentality rather than a traditional academic viewpoint. Market research through industrial members and advisors is key to offering successful industrial courses. A questionnaire distributed via the IAB with potential topics of interest for courses is a fairly easy mechanism used to gauge industrial interest. Industry should also be surveyed for preferences about location, cost, credit, and format.

If a live short course is offered, a venue that is convenient for the target market needs to be selected. It can be either on- or off-campus (e.g., in a hotel or conference center). That decision in turn may affect which university or universities sponsor the course, based on availability of resources and meeting facilities.

9.5.5.2 Choosing and Recruiting Course Instructors

Finding champions—professors and instructors—who want to offer courses geared toward industry interest (as expressed in a market survey) is key to success. Soliciting course ideas and topics from professors and industry instructors is good practice. At times, it may be necessary to recruit professors and/or IAB members to offer a topic requested by industry. But in general it will work better if the instructors are enthusiastic about the idea. It is good to have a mix of professors and industry instructors. The expertise and reputation of the instructors (marketability), their availability, and payment mechanisms need to be addressed. The instructors will need to be paid by the entities collecting the registration fees. It is important for the institutions collecting those fees to determine what financial mechanisms are available to pay the instructors. Subcontracts (as independent contractors) are usually best for industry speakers or professors from other universities, while supplemental compensation may work best for professors at the sponsoring university.

9.5.5.3 Choosing the Delivery Mechanism

The partners involved in offering the course (university and industry) will need to develop marketing materials and mailing lists. Partnering with industrial trade organizations to distribute marketing materials and course publicity is very effective. In addition, targeted mailing lists can be purchased from commercial suppliers. A traditional rule of thumb is to expect a 1% return from a mailing list. If the course is offered via distance learning, the university distance learning departments are also key marketing partners.

For course delivery, it is ideal for a Center to have partners. Course books, meals, and breaks will need to be provided for short courses. Finding commercial partners to sponsor breaks or meals can be useful as long as advertising is restrained. For distance courses, mechanisms such as live or satellite video or streaming video can be a daunting challenge. Many ERCs offer distance-learning courses through their institutions' central distance learning or "industrial outreach" program offices, to help minimize such problems.

CASE STUDIES:

Non-credit Short Course*. The ERC for Environmentally Benign Semiconductor Manufacturing offered a successful non-credit short course on Chemical Mechanical Planarization (CMP). The course was offered by the Center with SEMATECH (a trade organization) and other industrial co-sponsors. An IAB member who was on sabbatical working at the Center was the driving force behind organizing five Center PIs from four universities to teach the course. The Center paid instructors' travel costs and honoraria. An initial planning meeting was held at the Center's annual retreat meeting, and planning continued via teleconferences. The Center education coordinator organized the course logistics. The Center compiled a mailing list with the help of its industrial members, and also worked with trade organizations in the San FranciscoBay area to publicize the course. In addition, the Center purchased a commercial mailing list and sent flyers to about 8,000 people in the semiconductor industry. The PI instructors also marketed the course through their contacts. Marketing efforts were successful in that 70 people attended the initial 1.5-day course, which was held in a hotel in Palo Alto in 1999. The majority of attendees were engineers or managers, with a significant number from sales. About 50% of the attendees were from the Bay area. The rest came from all over the US and as far away as Korea. This course was offered again in 2000 in Belgium, Japan, Taiwan, and California. For the second California course, the ERC partnered with a private training company, PTI Inc., to offer the course. The foreign courses had organizational partners and sponsors in those countries. Those sponsors handled the local logistics. These and three subsequent offerings of this course have been attended by a total of 280 people from more than 10 countries and representing 72 companies. More recently, the CMP course has been offered via streaming video and audio on the web, on-demand to enrolled industrial students via a commercial partner, Semizone.com (an affiliate of StanfordUniversity 's Center for Professional Development).*

Continuing Education Seminar Series. *The Mid-America Earthquake (MAE) Center offers educational programs to the earthquake hazard mitigation community, to emphasize products of the MAE Center's research and to build an audience of professionals in Mid-America interested in earthquake engineering and in the MAE Center's activities in particular. The Center's Continuing Education Advisory Committee identified a need for earthquake seminars with a regional concentration. Accordingly, the Center developed three series of seminars focused on earthquake hazard mitigation in Mid-America.*

Speakers were selected to match industry needs with the Center's areas of expertise, as well as representation from stakeholders and practitioners. Seminar locations were selected based on their close proximity to a large number of practicing engineers and engineering organizations that served as cosponsors. The seminars were advertised in cosponsor publications and mass mailings. CEUs were awarded to participants through the University of Illinois Office of Continuing Engineering Education. High-quality notebooks were produced that contained paper and CD copies of speaker presentations, research papers, and notes.

9.5.6 Collaboration and Partnerships (Outreach) with Schools and the Community

The first thing to remember about collaborations and partnerships is "don't reinvent the wheel." Find out what is currently available at each of your member institutions. Do they already have a K-12 component in place? What do they offer? Look at the community. Do you have science and technology museums that have outreach programs? What are the needs of the school systems in your area? What could you offer that might enhance their curriculum in the science and technology/engineering tracks? Diversity is a major issue for all Centers. What departments on your campus are addressing diversity? What minority-

serving institutions nearby would mutually benefit from a partnership with your Center? Should your Center apply for a Louis Stokes Alliance for Minority Participation (LSAMP) supplement from NSF? These are all good questions to answer before developing your outreach programs.

9.5.6.1 How Education and Outreach Partners Add Value

Just as an interdisciplinary research team produces outstanding results, having partners and collaborators for your education and outreach components helps develop well-rounded and beneficial programs. Collaborations and partnerships should complement your Center's expertise. Identifying offices, programs, and organizations that complement your education and outreach goals is a place to start. Set up fact-finding meetings with these offices to determine if there are some mutual goals and if collaboration would be beneficial. After that first meeting, you may not feel there is a good match. There is no obligation to take it further. If, however, there are mutual goals, you can determine what all parties could bring to the table. Whereas your Center might bring the engineering component, your collaborators might bring the school systems, the particular age group you want to impact, an industry that uses your technology, etc. For example, The Center for Education Integrating Science, Math, and Computers (CEISMC) on the Georgia Tech campus has as its main focus outreach to the K-12 education community. They were the first office the Georgia Tech/Emory Center for the Engineering of Living Tissues (GTEC) contacted when beginning to plan for K-12 outreach. Not only does CEISMC know the needs of the various school systems in Atlanta, but they had an established teacher program that GTEC could tap into to enhance its Research Experiences for Teachers (RET) program. GTEC offered the research experience the teachers wanted and CEISMC offered the structure to turn the research into lesson plans. It has been a very productive and beneficial partnership.

Having a diverse group of students, faculty, and staff is a major focus for NSF and your Center. It is very important to make connections with offices on each of your campuses that provide assistance to underrepresented populations. Determine what programs are available. Is there a way you could tap into this resource? It is also very beneficial to establish a partnership with minority-serving institutions (MSI). It may be possible to develop a partnership with an MSI at each of your Center's member institutions, or a strong partnership with one or two MSIs could benefit all campuses. It is very important when beginning to establish these partnerships that this be a win-win situation for all concerned. The minority institutions need to see that you are interested in offering their students and faculty valuable experiences. In addition, NSF requires each ERC to develop a partnership with a Louis Stokes Alliance for Minority Participation and an Alliance for the Graduate Education of the Professoriate. The purpose is to engage the broad base of minority students and these alliances. These students usually participate in the ERC's REU program or other research efforts that involve graduate students.

It is important in partnerships like those described below to determine what the Center wants from the collaboration and what the other parties want and need. Coming to an early consensus will help get the project started on a positive note and proceeding productively.

CASE STUDY: *The VaNTH ERC for Bioengineering Education Technologies has contracts with the University of Memphis and the University of Texas-Pan American—both minority-serving institutions—and Fisk University, an HBCU (Historically Black Colleges and Universities) in Nashville, TN. In all contracts, it was very important to balance the need for financial, intellectual, and infrastructure support. The needs and the programs may be different at each partnering institution. For example, for all three of these institutions, funding is provided for new seed research projects. At FiskUniversity, there is also the added value of intellectual support for participating Fisk faculty and funding for infrastructure (equipment). There are also student exchanges from all the universities for VaNTH's REU program.*

CASE STUDY: *GTEC, the Georgia Tech/Emory Center for the Engineering of Living Tissues, has established a partnership with the AtlantaUniversityCenter (AUC), a consortium of five HBCUs in the Metro Atlanta area. GTEC sought the partnership for several reasons. It wants to enhance its biology-based research initiatives and is providing funding for two seed projects for the MorehouseSchool of Medicine for research that is closely aligned with GTECs. The Center will also provide an avenue for undergraduates from Morehouse and SpelmanCollege to do research in the GTEC labs at either Georgia Tech or EmoryUniversity. The last component of the partnership will provide partial summer funding for Morehouse and Spelman science faculty to work in GTEC and MorehouseSchool of Medicine laboratories to experience new techniques, equipment, and applications. This partnership is unique in that GTEC is also partnering with theGeorgia Tech College of Engineering (GT CoE) and their Dual Degree program. This program allows undergraduates to do their first three years at Spelman and MorehouseColleges, and then transfer to Georgia Tech into an engineering curriculum. A program coordinator was hired to work with GTEC, GT CoE, and the AUC to encourage students to participate in the Dual Degree program. Supplemental funding from NSF is making this partnership possible, in addition to the CoE sharing one-half of the cost of the Program Coordinator.*

9.5.6.2 Motivating Member Universities to Pursue Collaborations/Partnerships

Working within the Center's multi-campus organizational structure, the essential components of the education and outreach programs need to be decided. Next, determine what is feasible at each campus. Brainstorming on possible partnerships and collaborations will encourage member campuses to initiate contacts. Again, looking to see what is available in the community of each member institution is the best first step. Encourage each campus to think creatively. Other suggestions for motivating member institutions to pursue collaborations might include:

- Ask the Student Leadership Council what they would like to develop and present for outreach. Ownership in the programs greatly increases participation of your graduate and undergraduate students.
- Create a culture of appreciation for education as well as research. Just as your Center funds research projects, you should fund specific ventures that focus on education issues, i.e., curriculum development, precollege educational modules, and involvement of undergraduates in research projects.
- Develop a matrix for the internal review of research projects for the purpose of funding. Projects can be strongly encouraged or required to have an educational component in order to receive funding. Those that do not have an educational component would be less likely to be funded. Collaboration with community organizations can give added weight to a project proposal.

9.6 INDUSTRIAL COLLABORATION AND TECHNOLOGY TRANSFER

During the initial organization and implementation of a multi-institution ERC, extra effort is needed to obtain buy-in for the industrial program from all of the partner institutions. The preexisting industrial relationships among the academic partners need to be recognized, nurtured, and augmented to build a new base of industrial members across the Center. A new membership agreement needs to be created. Intellectual Property (IP), technology transfer, and industrial funding (membership, research funds) need to be discussed, negotiated, and codified into agreements. The Industrial Liaison Officer (ILO), a staff member at the lead university, leads this effort and has the additional task of working with the Principal Investigators (PIs), students, and industrial partners from all of the partner institutions. The structure of a multi-institution ERC is more complex than that of a single-institution Center; the relationships between the partners are more complex; and requirements of the ILO task are more demanding.

As a multi-institution ERC pulls together its dream team of academic and industrial collaborators, it faces several challenges. It must adapt to existing working styles and modes of operation, while accommodating different personalities, campus cultures, and industries. And it must create a viable model to enhance intercampus integration and industrial interactions.

The following paragraphs focus on issues common to multi-institution ERC industrial collaboration. Examples and case studies are provided to illustrate how multi-institution ERCs structure their industrial consortia, secure buy-in, and share resources. Some examples will illustrate how membership agreements and IP policies are established. Other examples will describe what is done to enhance interactions with industry, increase involvement, and motivate all partners. The collective experiences conveyed in these examples should serve as good references for both new and existing multi-institution ERCs.

9.6.1 Getting Started

Before starting the effort to build the Center's industrial program, it is important to recognize the added value of a multi-institutional ERC as it can greatly enrich both industry and university partners. Industry gains multidisciplinary, innovative technologies and resulting IPs; expanded technology transfer opportunities; access to multi-campus graduates as possible employees;, and collaborative possibilities with multi-campus researchers. Participating universities gain additional funding (from industry membership, NSF, multidisciplinary projects) for research and publication, and access to a broader spectrum of industry partners for more R&D and technology transfer opportunities. Recognizing each party's motivation helps in building an infrastructure that will flourish.

9.6.1.1 Securing Buy-in and Commitment

One of the start-up challenges is to secure cooperation and support from university administration on all partner campuses as well as their respective Technology Transfer Offices (TTOs). ERCs that provide industry membership funds to leverage grant-funded research also need to negotiate an overhead rate structure that optimizes both industry membership and research funding.

If a new ERC has pre-existing industry partnership programs at one or more of its partner universities, the Center must establish a membership agreement that incorporates the cultures of all partner institutions, and develop a membership structure that will ensure an easy and transparent transition for existing members. If no such pre-existing industry partnership program is in place, one suggestion for initiating a membership agreement is to request sample agreements from existing multi-university ERCs for reference. Another useful approach for potential partners is to make it clear that three things are expected from/for partners: (1) to contribute to the ERC; (2) to participate actively in the work of the ERC; and (3) to benefit from the ERC. If these goals are articulated early in negotiations, expectations are clear and subsequent unpleasant turns in the relationship can be reduced.

CASE STUDY: *Realizing the importance of securing buy-in and commitment from its five core partner universities, the Center for Power Electronics Systems (CPES) began a series of teleconferences with pertinent university officials and TTOs from team universities during the ERC proposal stage. The outcome of these discussions was a draft of a Memorandum of Agreement (MOA) that was eventually refined, approved, and executed by all partner campuses. The MOA helps to clarify the team's agreement regarding membership structure, intellectual property rights, and mechanisms for technology transfer.*

CASE STUDY: *An existing industry membership organization, the Industry Educational Partners at Georgia Tech, was consulted at the ERC proposal stage for industry input. The industry members, consisting primarily of large medical device companies, strongly suggested the inclusion of EmoryUniversity to gain participation, access, and guidance from clinical groups relevant to the biological systems in the proposal. The industry members thought this partnership would be essential not only to successfully competing for an ERC, but also to the overall, long-term success of the Center. Consequently, the commitment of Emory University was secured and the formation of the Georgia Tech/Emory Center for the Engineering of Living Tissues (GTEC) was proposed for ERC funding, with the Educational Partners Program as a component. The buy-in of the industry members and transfer of the industry program to GTEC was facilitated by including them in the proposal process. They now benefit from the value-added relationships with Emory and Georgia Tech. Because the GTEC industry program was focused on tissue engineering, one member dropped its membership since tissue engineering was not a priority area for the company. With that exception, however, all the other original members have stayed involved and strongly support the Center.*

9.6.1.2 Structuring a Program to Benefit All

A multi-institution ERC is usually comprised of a diverse faculty with specialized expertise in complementary areas. Such a multidisciplinary program inevitably attracts industry members with varying interest levels. To serve the needs of a broad spectrum of industry, some ERCs have found that a tiered membership structure is effective because it offers flexibility in terms of financial commitment and collaborative opportunities with the academic institutions.

Although the NSF ERC program prefers that contributions from industrial and practice partners be in cash, to provide maximum operational flexibility for the ERC, in-kind contributions are possible and are welcomed. Companies in financially difficult periods, including start-up, often find it easier and more beneficial to contribute in-kind than in cash. Examples of in-kind contributions include hardware, software, or even support for students under certain conditions. Terms and extent of in-kind contributions must be administered fairly across companies and academic partners; i.e., no favoritism should be shown to a particular company or to a particular industrial or practice partner.

CASE STUDY: *The Center for Extreme Ultraviolet Science and Technology (EUV ERC) offers a tiered membership structure with three levels of corporate membership: Full, Associate, and Small Business Corporate Member. The Full Corporate Membership is $50,000 annually, Associate is $25,000 annually, and Small Business (less than 100 employees) is $5,000 annually. Credits for separate contracts which add substantially to the Center's needed infrastructure, equipment, or other valuable resources are given. At a minimum, Full Corporate Members must donate $10,000 in cash annually. The $5,000 annual fee for Small Business has made this level*

particularly attractive and has brought the EUV ERC a significant amount of industrial participation early in its existence. Companies large and small have joined for a seat at the table, to see the emerging technologies firsthand, meet the faculty and students directly, have potential access to the IP, and in some cases, receive help with simple tasks or components which help them get into the business.

CASE STUDY: *CPES offers a tiered membership structure that includes four levels of participation—Principal Plus, Principal, Associate, and Affiliate. Principal Members pay $25,000 per year, and Principal Plus Members pay an additional $25,000 to gain the option of participating in a mini-consortium for focused research or sponsoring a fellowship for exploratory research within the Center's strategic plan. In addition to basic member benefits, Principal-level members also have early access to CPES-developed intellectual properties. Principal Members guide the Center as Industrial Advisory Board (IAB) members and work closely with Center researchers as research champions. Associate Members pay $10,000 per year and have easy access to the Center's research results, CPES researchers, and the state-of-the-art facilities. Affiliate Members include contributing WEMPEC members, small start-ups, and suppliers that are interested in making in-kind contributions to the Center in exchange for access to Center information as well as networking opportunities with Center personnel and other industry partners.*

CASE STUDY: *At the ERC for Biomimetic MicroElectronic Systems (BMES), Center membership funds are leveraged with sponsored research funds. BMES membership categories include Senior Members and Technology Members. Senior Members commit $50,000 per year for three years, serve on the IAB, and are mentors for technology development. They are in the best position to help define industry needs and influence research direction. They participate in research program reviews, have early access to Center-developed IPs, and are given first licensing opportunities. Technology Members commit $10,000 per year for three years. In addition to receiving the Center's research reports, Technology Members are invited to the ERC campus once or twice a year to meet-and-greet students for exploring summer internship and employment opportunities.*

CASE STUDY: *GTEC has structured their membership fees according to the size of the companies participating. This was done to make the industry membership program accessible to small ($5,000 per year) and mid-sized ($10,000 per year) companies, as tissue engineering is considered an emerging industry with a limited industrial base. Even within large companies ($15,000 annual membership fee), the number of groups working on tissue engineering is limited, and the company might not have tissue-engineered product revenue streams. The fees are kept low to make the program inclusive, since there are a limited number of companies interested in and capable of investing in this emerging industry. Reduced fees for not-for-profit organizations are also considered.*

CASE STUDY: *The Business and Industry Partnership (BIP) at the Pacific Earthquake Engineering Research Center (PEER) involves industry and government partners that participate in the Center's research and education programs. BIP members are given preferred access to PEER research and products as well as preprinted publications via the PEER website. They have the opportunity to interact with PEER students and faculty and are welcome to attend PEER meetings to provide input on research direction and learn about the latest research findings. Membership contributions vary from $500 to much larger amounts, based on size and participation. Crucial PEER partners, such as the California Department of Transportation, California Energy Commission, and Pacific Gas and Electric Company, are highly involved in defining issues, formulating projects, and funding the specific research.*

CASE STUDY: *The VaNTHEngineeringResearchCenter in bioengineering educational technologies is unique among ERCs in that its research and development focus is on engineering education and associated learning technologies, not engineering* per se. *Several VaNTH partners are leading developers and vendors of engineering education and application software. These companies are encouraged to donate their software for educational purposes; that is, for use in the development of courseware and testing of instructional modules among the student populations of VaNTH research partners. Such contributions have several advantages to both VaNTH and the contributing company: (1) A clientele of users is established among students. If their experience is positive, students who learn to use software during their formal education are more likely to request and continue to use it during their work experience. (2) Instructors who develop educational experiences can provide valuable feedback on product design to software companies. (3) Companies, particularly smaller ones for which cash flow is a problem, can count the value of that software and its maintenance (usually discounted by prior agreement with NSF) toward membership requirements.*

The importance of partnerships with smaller companies cannot be overemphasized. These companies frequently benefit from advertising their relationship with the academic partners of an ERC, are often involved with cutting-edge technology to which

more established partners do not have access, and are flexible enough in organizational structure to be more immediately responsive to ERC initiatives. For example, the VaNTH ERC has profited from many hours donated by a small company specializing in multimedia education to help produce bioengineering learning materials. Another small company, as a result of the VaNTH partnership, has helped develop innovative procedures in engineering design that have been emulated in medical as well as engineering curricula. Still another small company has become the second-largest employer in its home county through, among other strategies, taking advantage of VaNTH students and resources in developing learning materials and production strategies. Finally, it should be noted that small companies that are brought in the door at an affordable level have the potential to grow to higher levels in their involvement with the Center.

9.6.1.3 Incorporating Pre-existing Industrial Consortia

To sustain a robust industrial consortium, an ERC must be successful in recruiting new companies and retaining existing members. For multi-institution ERCs with pre-existing industry partnership programs, it is crucial to provide a seamless and transparent transition for existing members.

CASE STUDY: *Two of the five core CPES academic partners have successful pre-existing industrial consortia. The challenge is to develop a strategy to merge these consortia seamlessly into a CPES consortium upon which the Center can build a robust industrial consortium. To achieve this goal, Virginia Tech, the lead institution, folded its pre-existing industrial consortium, VPEC, into CPES, while selected WEMPEC members from the pre-existing UW-Madison consortium who had a relevant interest in the CPES program became CPES Affiliate Members. These members contribute one third of their membership fees to support CPES research activities relevant to the CPES strategic plan.*

9.6.1.4 Membership Agreements

A viable membership structure is one that attracts broad-based participation because it provides appropriate benefits to industries with varying needs and interests. Once the structure is agreed upon, membership agreements are reviewed and approved by university and legal counsel officials. For ERCs established at institutions that have pre-existing Centers, the road to securing buy-in and gaining institutional support can be significantly smoother. Using existing working models, the process for establishing multi-university agreements and IP policies can be highly efficient. For ERCs that have pre-existing industry programs, it is also important to clarify the new plan and transitional process for existing industry partners.

CASE STUDY: *As the second ERC established at the University of Southern California, the Biomimetic MicroElectronic Systems (BMES) ERC enjoys the advantage of the ERC campus culture shaped by the older Integrated Media Systems Center (IMSC). Based on the IMSC model, BMES was able to streamline the process of setting up its industry membership structure and was successful in implementing a cross-campus IP policy that is stronger than a Memorandum of Understanding (MOU).*

CASE STUDY: *CPES includes five core academic partners, two of which have pre-existing industrial consortia. Knowing the importance of ensuring that existing industry members are clear about the transition and happy with the program's features, CPES added a special Q&A session during the Center's first annual seminar and invited industry partners to discuss the new program, raise their concerns, and offer feedback and recommendations.*

CASE STUDY: *At the University of Michigan's Wireless Integrated MicroSystems (WIMS) Center, industry membership agreements are evergreen, allowing automatic membership renewal unless either party opts out. This mechanism has dramatically reduced the burden for corporate champions to obtain executive-level signatures every year.*

9.6.1.5 Unique Aspects of Earthquake Engineering Research Centers

The ultimate mission of Earthquake Engineering Research Centers (EERCs) is to save lives and minimize earthquake-induced economic losses. Due to the broad societal impact of earthquakes, both private corporations and government agencies are integral partners of EERCs. At PEER, industrial corporations such as Pacific Gas and Electric Company and state agencies such as the California Department of Transportation and California Energy Commission have strong and long-term relationships with the Center. Utilizing leveraged funding, these government and industry partners work closely with PEER to develop long-term research programs, aiming to achieve the collective goals of addressing seismic issues and problems, reducing loss to human lives, and minimizing damage to the electrical network, highways, buildings, bridges, etc. These Centers are different from other ERCs due to the direct societal nature of the work and the heavy involvement of government

agencies from the regional to the local level.

9.6.2 Building a Strong Industrial Constituency Across Multiple Campuses

The ILO needs to recognize the existing links and potential links between companies, Principal Investigators, and students in the ERC. He or she must build or reinforce bridges between the company and the ERC by communicating the benefits of the relationship to both parties.

9.6.2.1 The Industrial Liaison Officer—A Resource for All University Partners

To maintain strong intra-campus connectivity with industry, the ILO must play a central coordination role and serve as the primary point of contact. The ILO should be both people- and detail-oriented, and be well-regarded by both ERC faculty and industry. In addition to recruiting industry members, the ILO also needs to energize effective interactions between researchers and industry champions and act as the liaison between the TTOs on the partner campuses. To enhance effectiveness, each partner university could also designate a campus liaison to support the ILO, as a resident person would better understand the people and infrastructure on his/her respective campus. The ILO should work closely with the Center's research manager(s) and IP offices, act as industry's advocate, and serve as the primary provider of customer service. In short, the ILO must be the "glue" that holds the academic and industrial communities in working harmony.

CASE STUDY: *Keeping all Center constituents (multiple university faculty, students, and administrations; outreach participants, and industry members) informed of activities, special initiatives benefiting industry, and scientific developments is critically important. GTEC publishes an industry newsletter biannually (fall and spring) that highlights faculty/student activities and awards, new publications, patents issued or applications published; introduces new industry members or new faculty; and features short news pieces to keep everyone connected. The newsletter can be distributed to a larger industry community as a PDF file via email or downloaded from GTEC's website to raise the profile of the Center and potentially recruit new member companies. Samples of the Center's* Expressions *newsletter can be found at* http://www.gtec.gatech.edu *under "Center Publications."*

CASE STUDY: *At VanderbiltUniversity, the VaNTH industrial liaison group has several additional responsibilities that facilitate industrial contact. Dr. Jerry Collins, VaNTH's ILO, is the recipient of an industrial internship award from the Whitaker Foundation. Internship placement with companies, some of which are VaNTH partners, provides feedback on how VaNTH students perform in conditions of adaptive learning (a development goal for VaNTH), as well as suggestions for improving the instructional milieu. Dr. Collins has also served as chair of the Interface with Industry Committee of the Biomedical Engineering Society, and is current co-chair of the Education Committee of the Tennessee Biotechnology Association and president of the Tennessee Biomedical Engineering Consortium. This visibility and activity among national and local industrial and professional organizations affords numerous opportunities for development of ERC industrial partnerships.*

Additional partnership opportunities can come from follow-up of summer internship and permanent employment opportunities developed through an active university CareerCenter and Alumni Office. Strong relationships with such offices on every campus of a multi-university ERC should be developed by the ILO and her/his associates.

9.6.2.2 Industry-student Connectivity

To build and maintain a strong industrial collaboration program, ILOs must cultivate connectivity between students and industry. Initially the level of industry connectivity will probably differ from campus to campus, based on prior industry-faculty relationships. As the ERC evolves, it is important to initiate and maintain efforts that will maximize industry-student connections on all campuses.

The natural way to increase connectivity between students and industry are to use the events that bring the industry and academic communities together, such as IAB/SLC meetings, annual symposia and site visit, technical exchange meetings, and hiring opportunities. In planning an ERC symposium or site visit, the ILO and Education Director can arrange for student and industry interactions; for example, a poster session would bring industry representatives and multi-campus students together to meet and discuss research of mutual interest. Industry representatives can be called upon to review and vote on student posters or presentations, leading to an award. The Education Director can compile a student resume booklet to be distributed at the Industrial Advisory Board (IAB) meeting or at the poster session. Graduating students can be invited and introduced at the IAB

meetings. Receptions or dinners can be used to encourage networking by pairing students with industry representatives.

When a student's work reaches the intellectual property stage, the ILO can coordinate an effort to bring the student (with mentor and guidance) and appropriate industry partner together to explore commercialization possibilities. Conversely, an industry partner can help a student recognize the commercial potential of some of his or her work and, through the ILO or Education Director, help the student obtain the proper protection (patent, copyright, etc.).

In general, multi-institution ERCs involve students from all partner campuses in annual meetings, workshops, and symposia so they can present their work and interact with industry participants. In addition, some ERCs also engage industry research champions in intra-campus research meetings for technical updates, providing more opportunities for industry-student connectivity. These interactions sometimes lead to students being invited to present their work at the company site, resulting in higher visibility and possibly leading to summer internships and employment opportunities.

CASE STUDY: *In the VaNTH ERC, Vanderbilt has a strong undergraduate internship program and NorthwesternUniversity has a strong undergraduate co-op program (undergraduate programs at the University of Texas, a VaNTH research partner, and the University of Memphis, a VaNTH academic partner, are still under development). Placement of bioengineering students in both internship and co-op positions is sought and encouraged by VaNTH. After the training period, co-op students, interns, and industrial mentors are asked to respond to questionnaires patterned after ABET-desired outcomes for accredited educational programs. Assessment of responses provides benchmarks of student performance and VaNTH effectiveness.*

CASE STUDY: *The GTEC Student Council has developed a short course pertaining to research and development in industry called **L**earn about **I**ndustry **f**rom the **E**xperts (LIFE). The LIFE short course assists in preparing students for future industry positions or collaboration. This program draws from the GTEC industrial partners' expertise and enhances student-industry relations. The course introduces students to the events that occur within industry to bring a product through research and development to the market—taking a research idea from the bench and delivering it to a patient in the form of a product. Topics include research and product development in industry, FDA regulatory issues, market-driven research and development, and other topics designed to expose students to the processes involved in commercializing a research idea. Students are provided with notebooks for the course, and those attending 75% or more of the talks are given a certificate of achievement.*

CASE STUDY: *To improve industry-student connectivity, the CPES IAB's Working Group on Communications invites the Center's Student Leadership Council to join their monthly teleconferences so they can better understand student needs and exchange ideas. As an outcome of these discussions, a dedicated meet-and-greet function became an annual activity for students and industry participants to mingle in an informal setting. In recent years, these interactions evolved into the highly successful face-to-face IAB/SLC joint meeting held during the annual conference. In these meetings, industry and students openly share issues and concerns and discuss possible means to further improve industry-student connectivity. Another activity that has proven to be of great value to enhancing student experience is that students are given the chance to organize the Center's annual conference by joining the Student Conference Organizing Committee.*

The CPES IPPF plan provides an additional mechanism for direct transfer of knowledge from researchers to industry, as IPPF members are invited to join quarterly telecons to discuss with student researchers the value of their innovative concepts for possible patent protection.

9.6.3 Interacting with Industry Partners in a Multi-University Environment

A multi-university ERC must recognize the research needs of the ERC's industrial partners and, to the extent possible within its strategic plan, guide its research to satisfy its partners' needs. The IAB plays an important role as the voice of the industrial partners by communicating clearly their technological and research needs.

9.6.3.1 Modes of Communication for Intra-campus Collaboration

ERC research direction should be aligned with industry trends and long-term needs, so that the research is relevant for eventual commercialization. To accomplish this objective, ERCs must collaborate closely with industry in technology development and transfer. ILOs are responsible for facilitating this process across the campuses.

CASE STUDY: *As the CPES research program matures, the number of cross-campus joint projects increases, allowing more opportunities for multi-campus integration and collaboration. CPES thrust leaders jointly decide on how to group the projects into clusters for team discussions. Student leaders organize the biweekly team teleconferences and invite research champions to join them on a monthly basis for progress updates and industry feedback. In preparation for these meetings, agenda and reference materials are disseminated in advance to industry participants. Those who are unable to participate can retrieve student presentations posted on the Center's password-protected website.*

CASE STUDY: *VaNTH has held at least three and as many as four meetings each year at VaNTH research partner sites. IAB meetings are held at two of these (the Austin spring meeting and the Nashville site visit), and Industrial and Practice Partners (IPP) and potential partners are invited to the others as well. When appropriate, IPP members give presentations at these meetings. One advantage of distributing the sites of these meetings is that IPP partners can attend meetings in their geographical vicinities with minimal disruption and expense. Regional meetings are also an excellent method for inviting and recruiting potential new partners.*

CASE STUDY: *To optimize cross-campus collaboration, all partner campuses of the WIMSCenter use the Polycom system as their common mode of communication. This audio/video capability has enabled more effective communication with regard to research collaboration as well as Center administration.*

9.6.3.2 Industry Advisory Board

The IAB represents the industrial partners. It meets to review the research of the multi-university ERC, to discuss needs of the industrial partners, to communicate their needs to their university partners, and to carry out the annual industry SWOT (Strengths, Weaknesses, Opportunities, and Threats) analyses for the ERC's and NSF site visit team's reference. Some ERCs open IAB participation to all industry members. However, for multi-institution ERCs with large industry membership, it may be more effective to keep the IAB to a manageable size. Following are examples of how some of the ERCs organize their IAB and related activities.

CASE STUDY: *At PEER, selected representatives of the Business and Industry Partnership, plus representatives*

of key government agencies providing funding for PEER, are members of an Implementation Advisory Board which advises PEER on its strategic plan, research projects, implementation of research results, and new opportunities for funding.

CASE STUDY: *CPES Principal-level Members have a stronger interest in closer collaboratin with the Center and demonstrate their commitment by making higher financial contributions. These companies have a guaranteed seat on the IAB. Associate members are mostly interested in basic membership benefits and are offered possible IAB representation by election. In general, the CPES IAB consists of 30 industry representatives.*

To enhance its effectiveness, the IAB forms an Executive Committee (ExCom) to filter and identify issues for broader IAB discussion. The IAB ExCom holds monthly teleconferences, while the full IAB meets three times a year—two via telecons and one face-to-face meeting held in conjunction with the Annual Meeting. To provide a forum for all industry partners to interact with each other, the face-to-face IAB meeting is open to all members. Throughout the year, industry partners are given access to program updates posted on the Center's password-protected website, and are kept abreast of IAB activities via the distribution of IAB telecon meeting minutes.

In addition to the IAB ExCom, there is also the IAB "huddle group" that includes the IAB Chair, Co-Chair, Secretary, Center Director/Co-Director, Technical Director, and ILO. IAB Huddle meets on the phone every week for informal updates and dialogue. This tiered model has proven to work very well in ensuring effective communication between CPES and its IAB.

9.6.3.3 IAB Working Groups

When the IAB has identified certain issues and needs industry attention and support, IAB may decide to form a focused working group and charge it with a specific objective. As the working groups carry out their mission, contributing members may go within their own companies to seek help and consult experts, thus allowing the Center to gain expanded support from additional industry advocates and mentors. This model has proven to be quite effective for ERCs that employ it.

9.6.3.4 Industry Champions

Industry champions are advocates of specific research areas and serve as mentors to the Center's researchers. As an added benefit, cross-campus interactive opportunities on technical matters are offered to representatives of Principal-level member firms, as champions who interact closely with ERC researchers can ensure direct technology transfer. Keeping industry champions actively engaged is the collaborative endeavor of ILOs and research thrust leaders. Oftentimes, faculty researchers make the initial connection with industry, and the ILO continues the effort by making follow-up calls, defining champions' role, clarifying expectations, and facilitating communications. ILOs of multi-institution ERCs must make the extra effort to work closely with the various cross-campus research leaders to ensure consistent and active industry involvement.

9.6.4 Intellectual Property and Technology Transfer

Technology transfer is important to all ERCs and can take many forms. However, IP issues vary in importance in different fields. For example, while early IP access is crucial for medical device companies due to the competitive edge it provides, IP is less important to Earthquake ERCs because their business and industry partners are equally interested in minimizing losses and reducing damage resulting from earthquakes.

9.6.4.1 Technology Transfer: Strategies and Mechanisms

The transfer of ideas and technologies from university partners to industrial partners is at the heart of the ERC/partner relationship. Technology can be transferred in many ways (presentations, publications, courses, joint research, student internships, contract and grant support, etc.). The more directly associated the technology is to the compnay's products, the more exclusive and valuable the technology transfer is to the customer. Ideas or technologies derived from sponsored projects and technology jointly developed under joint contracts or grants are generally the most valuable.

- *Joint projects and technology development—*

Working together, industry and universities can be more successful at obtaining government funding for joint research programs. Together they can obtain resources to develop technology needed by both. The transfer of technology then becomes automatic and provides a valuable justification for the ERC partnership and membership dues.

CASE STUDY: *The CenSSIS ASHERD Portal Program is a joint development of a nuclear detector for U.S. ports of entry by NortheasternUniversity and Bubble Technology Industries. Initially, it was a program to develop a spectroscopic portal for detection of nuclear materials in vehicles (trucks, cargo containers, cars, and trains). The successful completion of this development effort resulted in the procurement of a third contract between Raytheon, Bubble Technology Industries, and NortheasternUniversity to build portals for U.S. ports of entry.*

- *Finding effective models suitable for the diverse university cultures—*

Within a multidisciplinary, multi-university ERC where there may be multiple intra-campus joint projects, ILOs must make sure that industry has an easy way to interact with the various intra-campus project teams, and must also ensure that interactions with industry champions are consistent, efficient, and effective. For industry, the best mechanism for gaining the extra edge on technology transfer is to have company engineers serve as research champions, join IAB working groups, or participate in the Center's industrial residence program and work on-site with the Center's researchers.

- *Educating multi-campus researchers on IP-related issues—*

ERC faculty and student researchers often interact directly with industry. It is thus important to make sure that investigators and their students are fully aware of the Center's IP and non-disclosure agreements. Because jointly conducted research could lead to joint inventions, it is crucial that ERC researchers develop the important habit of documenting innovative concepts in IP lab notebooks as new ideas are conceived so as to support any inventions that may be disclosed under the team effort.

9.6.4.2 Developing an IP Agreement for Multi-university Centers

Multi-institution ERCs face the difficult challenge of developing an all-encompassing IP policy that is fully compatible with existing policies at partner institutions. Meeting with pertinent university officials and technology transfer officers from partner campuses to clarify the parameters, IP rights, and terms and conditions is therefore very important and should occur at the outset. Throughout this process, the ILO must act as the primary facilitator to ensure that the IP agreement serves industry well, while at the same time satisfying the requirements of the university partners. Participating universities should establish an inter-institutional agreement that outlines basic operating policies for the management of IP generated by each university and for collaborative efforts. A lead university may be identified to manage collaborative IP because of its expertise in specific IP categories. These agreements should be put in place early, kept simplified, and used as a guide when managing the Center's IP.

CASE STUDY: *The BMES ERC develops innovative medical devices with application horizons that may take up to 10 years for FDA approval. To justify long-term investments in academic research, most BMES industry supporters are interested in gaining the IP competitive edge. Recognizing that licensing opportunities for Center-developed IP is one of its core appeals, BMES was keen on establishing an IP access mechanism that is streamlined and efficient. With strong institutional support from its partner institutions, BMES was successful in establishing a multi-university IP agreement that allows central management and administration of Center-developed IP at the lead institution, providing the convenience of one-stop shopping for its Senior Members.*

CASE STUDY: *The CPES IP policy allows for a certain degree of flexibility within the framework. It states that if an invention is developed under NSF-funded core research, it will be managed in accordance with the IP policies of the university where the invention is disclosed. In the case of joint inventorship, which would be defined by U.S. patent law and the policies of the respective institutions and/or industry member(s), the home institutions of the joint inventors would decide who would be responsible for the prosecution of the patent and commercialization. In addition, partner institutions have agreed that Principal-level Members will be granted early access to CPES-developed technologies, the option to negotiate a reasonable license fee plus royalties, and the added opportunity for Principal Plus Members to credit annual membership fees towards license fees and royalties. To further streamline the IP protection process, CPES-Virginia Tech offers a novel option called the Intellectual Property Protection Fund (IPPF), a plan that allows Principal-level Members to pool funds for IP protection. IPPF members contribute $5,000 per year, jointly decide which IPs they wish to protect, and are granted a non-exclusive, royalty-*

free license to use these technologies. Not only has this mechanism greatly enhanced the IP advantage for Principal-level Members, it also allows researchers to publish their technical innovations without delay.

9.6.5 Sharing Industrial Funding Resources

Distribution of resources within a multi-institution ERC is a complex process. Each ERC conducts its distribution differently. Some funds are obtained with restrictions and others are not. Some funds are given to support specific activities at one institution or specific activities at a set of institutions. The distribution of funds and resources is as varied as the variety of sponsors. No matter what scheme for distribution is used, it must strongly support the ERC infrastructure and its technical efforts.

9.6.5.1 Planning and Allocations to Partner Universities

Industrial consortium funds generally are used to directly support industrial collaboration activities coordinated and managed at the lead institution. At times, however, ERCs may find it necessary to earmark a portion of the industry funds to support research or other program enhancement initiatives. In these cases, it is important to make sure that industry and university partners all agree with the purpose of the initiative and understand the funding allocation process.

CASE STUDY: *Under certain circumstances, faculty involved with GTEC may prefer to receive a major equipment allocation rather than receive research project support. For instance, faculty receiving most of their funding from the NIH cannot designate major equipment purchases to these grants. Faculty who are securing funding from outside the Center, but whose research clearly falls within GTEC's strategic research plan, may request the purchase of a major piece of equipment directly involved with that research. GTEC has purchased equipment (or provided matching funds) that would be impossible to buy with NIH grants in order to provide key enhancements and added capabilities that directly impact the Center through scientific advancements and collaborative research with other GTEC faculty.*

CASE STUDY: *To enhance domestic Ph.D. student recruitment and further emphasize basic research, CPES proposed to allocate some industry funds to create special graduate fellowships and fellowship supplements to support these initiatives. After receiving the IAB's endorsement, industry fellowships were established at the lead institution and allocated to specific campuses to fill their needs.*

CASE STUDY: *In addition to funds, another ERC resource is its students. Some of VaNTH's industrial partners request that they be allowed to hire interns or co-op students as part of their VaNTH commitment. The NSF allows the ERC to do that, partly because VaNTH is an educational ERC and student performance in an internship is an important testbed for the Center. Often, companies request interns from nearby VaNTH partners or from nearby home towns, because they feel their chances of retaining such interns as permanent employees are greater. VaNTH always tries to comply with those requests and coordinates its student searches accordingly.*