CHAPTER 2

CENTER LEADERSHIP AND STRATEGIC DIRECTION

2.0 CENTER LEADERSHIP AND STRATEGIC DIRECTION

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2.1 INTRODUCTION AND STATEMENT OF APPROACH

2.1.1 Guiding Principles

The authors of this chapter of the Engineering Research Centers (ERC) Best Practices Manual adopted the following basic principles: First, the Director is responsible for the vision that determines the direction of each center and inspires loyalty to its objectives. Second, there is clearly no single absolute and "correct" way to direct an ERC. There are, however, a series of choices that must be made as the process is undertaken, and each choice necessarily leads to a set of consequences. Every committee that is set up, and every administrative structure that is developed, will affect the center in ways that can be anticipated, at least in general terms, based on the cumulative experience of the 40-odd people who have directed ERCs for varying lengths of time at various stages in the 11-year life of these unique research centers. There are certainly many research centers in American universities, but the objectives, key features, and funding pattern of the ERC Program make these centers unique in several important ways. The directorship of an individual ERC is, therefore, a unique responsibility in the academic framework of the universities within which these centers are placed. (See Attachment 2-1, "Profile of an `Ideal' ERC Director.")

Because the success of an ERC must be measured in terms of the extent to which it has fulfilled the mandate set for these centers by NSF at their inception, it is useful to review their stated purposes. In 1985, when the first ERCs were established, the NSF clearly stated that it would allocate a relatively large amount of money outside of its traditional pattern of single-investigator grants to fund innovative, cutting-edge research centers that would enhance the global competitiveness of American industry. Very direct and effective integration with industry was implicit in the charter of the ERCs. These centers were to have a systems focus and to emphasize cross-disciplinary research and education. Consequently, an important change in the education of young scientists and engineers was envisioned and later reinforced as the ERC Program matured. It was clear from the beginning that the ERCs were to act as catalysts in the transformation of academic research in science-based engineering to produce centers that would establish world leadership in important areas of research, in industrial relevance, and in interdisciplinary education.

All the ERCs owe a debt of gratitude to the pioneering directors of the early "classes" of ERCs (1995, 1986, and 1987), who took on the complex challenges of the ERC concept and proved it could be done successfully (see text box). These are the Directors who had the original vision and who saw their centers successfully through at least their first (third-year) renewal reviews. They paved the way for the directors of the later classes who refined the ERC concept (classes of 1988 and 1990). Building on the experience of these first-generation ERC Directors, a second generation of Directors (classes of 1994-95 and 1996) have begun to expand upon the ERC concept to position their centers for success in the next century.

PIONEERING ERC DIRECTORS

Class of 1985

John Baras □ Systems Research Center (later Institute for Systems Research), University of Maryland and Harvard University

Mischa Schwartz □ Center for Telecommunications Research, Columbia University

James Solberg - Center for Intelligent Manufacturing Systems, Purdue University

Daniel I.C. Wang □ Bioprocess Engineering Research Center, Massachusetts Institute of Technology

Class of 1986

Taylan Altan □ ERC for Net Shape Manufacturing, Ohio State University

John Fisher □ Center for Advanced Technology for Large Structural Systems, Lehigh University

Douglas Smoot □ Advanced Combustion Engineering Research Center, Brigham Young University and the University of Utah

Arthur Westerburg □ Engineering Design Research Center, Carnegie Mellon University

Class of 1987

Thomas Cathey □ Center for Optoelectronic Computing Systems, University of Colorado

Theo Pilkington □ Center for Emerging Cardiovascular Technologies, Duke University

This chapter was prepared by a team of current and former ERC Directors (see Appendix A at the end of the Manual). They compiled a survey of issues in the directorship of ERCs that is appended to this chapter as Attachment 2-2. A large number of current and past Directors of ERCs were surveyed, and their responses form the basis of the chapter. It is hoped that the suggestions made herein □ although by no means absolute prescriptions □ will provide new or prospective Center Directors with a greater sense of confidence in their decisions. The intent was to provide assurance that, "If you choose the following options in directing an ERC, these consequences will probably follow."

2.1.2 Organization and Objectives

In an attempt to avoid duplication with other chapters (e.g., Chapter 3, "Research Management"),

and to provide useful advice to incoming Center Directors, this chapter will address the conception of an ERC, the daunting task of building and directing an ERC, and the set of decisions and actions that a new Director must take, roughly in the sequence that s/he must make them. Early in the life of an ERC the Director must decide to what extent s/he will delegate responsibility for specific aspects of the center's operations and s/he must then hire or assign employees or faculty members to fulfill these functions. The new Director also must work to will build harmonious relationships with the university's hierarchy and the relevant departments. This harmony may be jeopardized if, for example, s/he decides to press hard for contiguous space for the nascent center at an early stage in its development. Because not even the most heavily endowed universities can have all of the high-caliber faculty in the right areas that are necessary to execute the strategic plan of a good ERC, faculty recruitment is the most potent weapon that the Director has in hand to shape the center. One of the Director's main contributions to the center will, therefore, often be in the area of faculty recruitment and replacement, both externally and on campus. This contribution will extend throughout the life of the center and will depend heavily on the relationships that s/he has built with contributing departments and with the university administration.

2.2 THE VISION AND THE STRATEGIC PLAN

2.2.1 Creating the Vision

How are the theme and vision for a prospective new ERC developed? Every investigation or research agenda is based on a "genealogy," or cumulative body of knowledge or thought upon which the researchers base their current understanding of a field and from which they draw a vision of how the current state of knowledge might be advanced. It is useful to begin by preparing a clear summary of the state of the art in the field addressed by each ERC. This state-of-the-art summary should trace the development of the field from far enough in the past to capture the most important modern milestones in the field. This statement will be the starting point for the development of a strategic plan for the ERC. Later on, it will also provide a benchmark for assessing the progress of the center and the value added to the field by its activities.

Based on the historical developments in the field, each center then creates a vision of what can be accomplished in through the establishment of an ERC. Such a research vision should be based on the need for bringing various aspects of a particular field together to create the needed critical mass of interdisciplinary effort. The vision must be unique, or it will not strike a responsive chord in the NSF site review team that makes the initial recommendation for approval. The uniqueness of the vision normally will have educational ramifications, because it is essentially a breakthrough of sufficient intellectual weight to alter basic concepts in the field in which it originated. However, the vision must also be industrially related, and of sufficient practical importance to favorably affect the competitiveness of this country, if it is to gain the imprimatur of the ERC Program.

A consensus vision statement is then prepared that is shared with all center faculty and students. Each vision statement should identify the overall goals of the center, not only in research but also in education and industrial interaction.

Figure 2-1 illustrates a model for the relationship of previous developments in the field to the vision and goals of an ERC. Thus it suggests how the formation of a center can be seen in its historical perspective.

Since the main mission of the ERC Program is to make a positive impact on U.S. competitiveness in the global marketplace, it is important to understand and articulate the potential commercial impact of an ERC if it is successful in achieving its goals. One way to make a case for the significance of the impact is to start with an extensive market analysis showing the size (current or potential) of the industry affected. If successful, will the impact be the creation of a major new industry? Is there an existing major industry in which the ERC expects to stimulate technical advancement and growth? Will the role of this ERC be central in the future of that industry? These are all elements of the center's vision.

2.2.2 Participants in Vision Creation and "Buy-in"

The Director is the keeper of the lamp, the custodian of the vision on which each ERC is based. In many cases the Director is the author of the concept on which the ERC is based and the initiator of the application that obtained the original NSF funding. Here the research thrust area* leaders, center associate directors, and key industrial representatives usually have input into the development of the vision and have achieved consensus regarding it. Although the broadest possible "buy-in" to the vision is considered essential, it is difficult to involve more than this group of key individuals in these discussions; only one or two centers have involved participants down to the level of students in vision creation (and here it is necessary for the center to be preexisting in some form). In many cases an incoming Director will have inherited the vision from its author(s). In either case, a person must believe passionately in the vision on which the center is based, and in the objectives of the ERC Program, if s/he is to forsake the security of the successful, well-funded Principal Investigator (PI), beloved of Department Heads and Vice-Presidents of Research (or, in some cases, the successful corporate manager on the fast track to further advancement) and allocate 11 of the most productive years of his or her career to this enterprise.

As the originator and/or custodian of the vision of the ERC, the Director must be prepared to articulate this vision, in verbal or written form, to a wide variety of audiences ranging in sophistication from local service clubs to an NSF site review team. The Director is responsible for "tracking" the vision of the ERC, as it is expressed in the literature and in scientific discourse, to guarantee that the center is always at the cutting edge in research and at the forefront in the articulation of the perceptions that form the vision. The Director ultimately will

* A cluster of research projects managed as an integrated group to achieve one component of the center's overall strategic plan.

be held responsible if the ERC is ever eclipsed or surpassed in any major component of the vision on which it is based. Consequently, a Director must maintain continuously a clear perception of the linkages between the vision of the center and its research, education, and industrial activities and progress within them.

Our survey of current Directors has made it very clear that most centers rely on the Director to keep the vision clearly in focus for all of its members. Several respondents pointed out that visions are, by their very nature, long- range perceptions and that frequent updates are not normally advisable. However, since it is essential that all participants in an ERC buy in to the vision once it is articulated, it is useful to examine the sub-elements of the vision □ in the form of the strategic plan and thrust area research plans □ at regular intervals so that the faculty, students, and industrial members of an ERC community have the opportunity to become engaged with the vision and subscribe to it. In ERCs that are narrowly based on specific, fast-changing technologies, it may actually be imperative that the basic vision of the center be examined periodically, in cooperation with industry, and altered to suit the advancing state-of-the-art. However, most ERCs are based on much broader visions, and here the role of the Director is pivotal. Strategic plans are just that □ strategies. Thrust areas can assume a life of their own and begin to consume their leaders' scientific and engineering passions, but thrust areas are only more valuable than the sum of the efforts of individual PIs if they contribute to achieving the center's vision. It is the task of each Director to ensure that the vision is clearly seen and well served by the center through integrated research and education. In fact, it is a requirement of the ERC Program that the integrated whole of the center be greater than the sum of its individual parts.

2.2.3 The Strategic Plan

The ERC now must develop a broad strategy for achieving its vision. How can a cross-disciplinary center take advantage of the opportunity envisioned? This is its mission. Is it realistic? Does the ERC have the necessary intellectual horsepower to achieve success in this area?

One way to answer these questions is to form a "blue ribbon" panel of objective outside experts to evaluate the plans and personnel of a proposed ERC. If the answers are encouraging, then the next step is to develop a strategic research plan to achieve the vision and mission. In this chapter we will focus on the overall strategic plan for a new center. Chapter 3, "Research Management," describes the process for development and updating of the strategic research plan.

In contrast to the process of originating the center's vision, the process of strategic planning is more democratic. In some centers the initial planning is done by an executive committee consisting of the Directorate (including associate directors, if any), thrust leaders and/or senior faculty, and key staff such as the education and outreach directors. A smaller group allows faster convergence on the initial plan. But in most centers the process involves, either at the outset or subsequently, discussion and input from all faculty members and research staff. (At one center the plan is posted electronically for criticism by all center participants; commentary is circulated

via e-mail until all issues are resolved.) Usually the plan is reviewed and discussed at least annually by the Industrial Advisory Board (or equivalent). It can be tricky to avoid the natural tendency of industry to direct the details of the plan toward areas of short-term interest; the Director must be vigilant to filter out such influences and absorb them in the higher aims of the plan.

Revision of the strategic plan at the level of research thrust areas is almost continuous in most centers. Adjustments are made to specific goals and short-term approaches through frequent meetings of the Director, the thrust area leaders, and PIs in that area.

Strategic research planning and its implementation are discussed in detail in Chapter 3. Examples of strategic plans from three ERCs are presented at the end of Chapter 3 as Attachment 3-1.

2.3 STRUCTURING THE CENTER FOR SUCCESS

Delegation and staffing during the life cycle of an ERC is an issue of fundamental importance. The related questions of how much to delegate, what management and operations functions to delegate, and how best to accomplish this distribution of responsibilities should be addressed in the planning stages of the ERC and on into the initial stages of funding and implementation of the ERC proposal.

The structure of the center also bears directly on how well its participants and its various research thrusts will interact to achieve the cross-disciplinary flavor inherent in a successful ERC.

2.3.1 Director's Choice: How Much To Delegate?

When an ERC is funded by NSF it is probable that there will have been a personal moving force who has initiated the application and gathered the research team. It is equally probable that the initiator will have a large and well-funded research group, or it is unlikely that the application would have been successful. But it is apparent that the duties of the Director of an ERC are sufficiently challenging that they are very difficult to combine with those of a successful and busy PI or research group leader unless the person concerned is adept at delegation. For this reason the first, and one of the most important, choices that a founding Director will make will be the extent to which s/he delegates responsibilities within the center as it begins its progress towards its first date with destiny at the end of Year 3. The results of our survey clearly indicate that Directors of ERCs form a spectrum in this matter, ranging from the "one-man band" to the relaxed "master delegator." Some have gradually increased the delegation of responsibilities as the activities have become more routinized and the ERC more "settled." If the Director delegates too little, s/he risks eventual "burn-out" and the loss of his/her own research program and even the center itself. If s/he delegates too much, s/he is likely to lose control of the center and jeopardize its ultimate success. There clearly are some instances in which a strong and

well-balanced group of researchers persuades a faculty member with experience in administration to assume the directorship of a nascent center. These centers start with an advantage because the new Director will probably already know how to delegate effectively, but it is only advantageous if the Director is or can become the intellectual leader as well.

The founding Director should assess the importance of all the potential roles within the center and decide which to delegate and which to retain. Three major factors must govern the Director's choice of areas in which to concentrate attention: the peculiar strengths of his/her center team, and the overall interests of the center and, finally, the meshing of his/her own research interests with the welfare of the center. The results of our survey indicate that 7 of 12 Directors had effectively sacrificed their personal research program in favor of the interests of the center, while 3 had modified their research program and 2 had maintained them virtually intact. One reported that he had actually increased slightly the number of graduate students he supervises and had broadened the scope of his research due to exposure to the center's broad range of research. Some Directors said that they have been able to maintain the momentum of their personal programs by an increased dependence on postdoctoral fellows. Several reported that their research, not surprisingly, had become more cross-disciplinary, which helped sustain it. In any case, the Director's research must fit integrally within the scope of the center's research or it may be seen as a conflict of interest and a threat to the cohesiveness of the center. Such conflicts are viewed as serious by NSF, and must be resolved quickly.

2.3.2 Director's Choice: What To Delegate?

If the Director chooses to retain control of administrative and routine personnel matters, s/he will drown in details as the center grows to contain about 100 people. If the Director retains direct, personal control of financial matters, s/he can use this control to steer the center in detail, but s/he will be held responsible for every fiduciary ripple and s/he will encounter resentment when support is withheld or withdrawn. Experience teaches that, given the efficiency of sole autocratic command, a researcher can control and steer a research group of about 40 with some help from experienced staff and postdoctoral fellows; a few ERCs are "Mom & Pop" centers with a Director, a capable Assistant Director or Administrative Director with broad operational responsibilities, and several thrust leaders. But an integrated center with numerous faculty members and dozens of students is simply too large for one person to manage effectively. The sole exception occurs when a center becomes an "on-campus granting agency" and parcels out NSF funds and industrial money to fully independent PIs who run their own labs in the time-honored way, while the Director runs his/her own operation and acts as the reporting center. However, this approach is contrary to NSF policy and subverts the purpose of the ERC Program; such a center will not last long.

Over time, it has become apparent that the ERC Director can be aided in this complex role by a deputy executive officer who shares some of the leadership and management responsibilities in the ERC, in a manner that complements the leadership style of the Director. In recognition of this fact, NSF now requires all new ERCs to propose a Deputy Director. The Directors of existing ERCs without a Deputy Director or the equivalent should give careful consideration to

hiring a Deputy.

2.3.2.1 Administrative Areas Within the ERC

Because an ERC with NSF funding and average industrial, state, and university support constitutes a roughly $10 million enterprise, at least a basic administrative structure is mandatory for effective organizational and financial responsibility. (It is worth noting that two ERCs have encountered serious problems of financial mismanagement that could have been avoided by sound, professional fiscal control; see Chapter 6, Section 6.4.) Since the Director has, by necessity or by choice, probably delegated much of the administrative responsibility to trained specialists, the center will be shaped by the choices that are made in setting up this structure.

All ERCs have an Administrative Director (AD), or the equivalent, who is responsible for general management of the day-to-day operations of the center. The Director and the AD typically work very closely together; the smaller the administrative staff, the more this tends to be the case. The position of AD requires a strong generalist, and selection of the right person is critical. These individuals play a key role in the overall success of the centers. It is essential that the AD understand fully the vision of the center, its ideals, and its intended impact, and that s/he be treated as a partner in bringing them to fruition. The AD accepts the responsibility of implementing the center's vision in a manner acceptable to the university's bureaucracy. There must be a mutual respect, with the Director articulating the concepts and ensuring buy-in and the AD providing a reality check on what is possible and identifying ways to implement the concepts. (See Chapter 6 for a full discussion of this function.)

It must be noted, however, that the Director is ultimately responsible for any administrative lapses that may occur; consequently, it is important to maintain supervisory oversight and control of office management functions. One potential danger inherent in the small "Mom & Pop" center structure is that the Director may delegate too much authority to the AD. The Director and AD may then mutually reinforce each other's belief that "everything's fine," even if administrative problems have begun to appear. Such a situation actually did arise at two well-established ERCs, leading to the departure of the Directors.

The decision to hire specialists for other functions will affect the center in various ways. If an assertive accountant is hired, the finances of the center will be well managed; but at an extreme, account management may not be as flexible as the Director needs it to be to accommodate frequent changes in the strategic plan and new developments that demand shifts in resources. If a computer specialist is hired the center will have excellent data handling, good communications, and an attractive image on its home page. If the industrial interface is handled by administrative staff on a part-time basis, the Director will be the *de facto* salesman for the center. On the other hand, if an aggressive industrial liaison officer and technology transfer specialist is hired who can convince the PIs to buy into the industrial interface, the industrial interface will burgeon and there will likely be a strong technical connection with industry through the PIs. If the details and the policy of interdisciplinary education in the center are managed by a part-time education committee, students will be trained in their home departments and assembled in the center for

occasional seminars and NSF site visits. But if an imaginative and personable education specialist is appointed, the students will make their home and form their friendships and loyalties in the center □ and may be able to fund their own education with competitive scholarships.

The administrative infrastructures of centers thus range from a few people gathered tightly around the Director to small armies of specialists working for the benefit of the center, and each choice that is made will affect the kind of center that will emerge at the critical third- and sixth-year review milestones. Also critical is the decision of what structure to use for reporting and supervision (discussed in section 2.3.2.3, "Mechanisms of Delegation"). The choices made in setting up the infrastructure of the center are matters of policy, and not of financial expediency, because at least two of the key responsibilities (technology transfer and education) may become largely self-funding. The administrative structure of the center must be set up thoughtfully by the Director, who must ensure that all major policy matters remain firmly under the control of center leadership and are complementary to the primary objectives of the center □ industrially relevant cutting edge research and team-based interdisciplinary education.

The size of the administrative teams that run the daily affairs of ERCs varies between 3 and 19,[*] approximately. The Director who chooses the smaller, "tighter" option will retain more control over the operations of the center, because s/he can readily meet with the key people and set policy through simple conversation. The expanded team will offer greater possibilities for growth for the center, and for participation by more of its members, but the Director will probably have to relinquish some of his/her personal control and may be forced to appoint an overall manager from among this large group of center employees □ or, preferably, to bring in a Deputy Director or Executive Officer. Administrative teams are easy to expand but difficult to contract; like many well-established units in industry and government, they often have an effective life of their own and a strong instinct for self-perpetuation. For this reason, the establishment of a large team constitutes a commitment to the center, on the part of the Director and the university administration. This commitment itself may drive the conversion of the ERC to an ongoing research/education entity after NSF support is terminated.

2.3.2.2 Program Areas Within the ERC

The three pillars of the ERC Program are research, education, and technology transfer. However, it is clear that the first (research) is a *sine qua non*, in that there are no educational or technological advantages to be gained from research if it is not outstanding. Also, all ERC Directors quickly come to understand that NSF site visit teams have been instructed by NSF to view research as the first preference "gate" when assessing the extent to which an individual ERC has succeeded in its mission.

If an ERC is to be a "better idea" center, rather than a "where do we get the money?" center,

[*] This large center operates extensive education and outreach programs with substantial additional support from the state government.

there must be a clear linkage between the strategic plan and research management and another linkage between research management and the management of finance and of education. In other words, decisions about the investment of center resources in specific research projects and in the support of students in specific research areas must be guided by a strategic plan in which the center is united. When that critical time of each year rolls around when decisions have to be made about how resources should be allocated to the various thrust areas, the Director will find himself in a situation that will be dictated by choices s/he has made at the outset. Either there will be a clearly stated strategic plan that makes the finance committee's job possible, or there will be a struggle for funds and the Director will have to make all of the final decisions. If there is a clearly stated strategic plan, the Director should be vigilant to discern the real authorship of key inputs to that plan. The strategic plan of a center can be manipulated by a small group of faculty with preconceived notions of what direction they want the center's research to take or, at an extreme, by a single strong personality □ often the Director □ who simply tells the troops that this is what s/he has decided. The smaller the coterie of influential insiders, the more NSF money there is for each individual in that group. But NSF Program Directors and site visitors can detect such a situation fairly easily and will not tolerate it. ERCs have failed to win renewal because their research program lost its cohesiveness and collapsed into a collection of loosely connected single-investigator projects. Effective strategic planning can prevent this tendency toward centralized self-interest.

2.3.2.2.1 *Research Management*

Chapter 3 deals specifically and in detail with research management in an ERC. However, management of this activity is central to the overall management and direction of an ERC and impinges on the success of every other area of center activity. The discussion here addresses research management in this broad context.

Research in an ERC is inspired and directed by the center's vision, as articulated by the Director and as supported by its members. The practical vehicle for the realization of this vision is the strategic plan, and the mechanism for its execution is the structure of thrust areas and testbeds found in most ERCs. As was described in Section 2.2, the Directors of most ERCs maintain firm control of the center-level strategic planning process; most decisions in research management are made by these Directors with the advice of a small inner circle of senior center researchers who comprise an executive committee. Several respondents regretted the lack of involvement of junior faculty in both the strategic planning and the research management processes, but cited difficulties in involving large numbers of people in these decisions. In a few cases, periodic retreats or cybersessions for the input of ideas have been employed as a means of involving more center members, and these have been proven highly effective in facilitating the development of a "center" perspective. But generally the responsibility for the planning and management of research remains centralized. At the detail level, however, junior faculty and students are more often involved in setting goals and milestones.

The most common and efficient apparatus for research management appears to be the appointment, by the Director, of a limited number (no more than five) of thrust area leaders who

then join a few senior faculty colleagues to form a research steering committee. This "closed" structure is inherently efficient, in terms of both reporting and decision-making, but it can stifle the growth and renewal of the center because it can be very difficult for new people and new research ideas to break into this exclusive club.

Several centers cite difficulties in closing down existing projects. Most report that they depend ultimately on the Director to make these hard decisions, but such ERCs have closed research management structures that may require that the research committee vote against one of its own members in order to accomplish this essential revitalization a process that is inherently conservative. A number of centers take industrial input (usually obtained at IAB meetings) on the relevance of projects heavily into account in deciding whether to continue them. Site visit recommendations are another source of input. Involvement of the IAB is said to be critical, along with the objective judgment of the Director, in overcoming the tendency of the well-entrenched "old boy's club" to maintain the status quo. One Director notes that these decisions are not made overnight; first, the need for action becomes generally recognized and then action is taken. It is easier to terminate unsuccessful lines of research if there is a detailed strategic plan with milestones; this makes it apparent when a project is going nowhere and/or no longer fits within the strategic plan. Another Director stresses that, "To maintain a high level of morale and cooperation, every attempt is made to discontinue projects with fairness and dignity." Open channels of communication, with emphasis on the ERC research as a team effort, help to soften the blow. Most ERCs provide support to the graduate student(s) involved for at least one semester after termination and try to accommodate them within other ongoing projects. Some centers use a scientific advisory committee to provide overall input regarding the quality of the projects, their relevance to the strategic plan, and the value they add to the state of the art in the field.

It is important to begin with the right number of research thrust areas. The "right" number may differ from center to center and field to field, and may also change across time. However, in general the fewer the research thrust areas, the easier it is to manage the research program (see case study).

CASE STUDY:

One of the early challenges faced by the Center for Advanced Electronic Materials Processing, at North Carolina State University, was the organizational structure of the research program. Because there were so many research areas of interest to the faculty, all of which could be justifiably incorporated into the center, the Center began with ten thrust areas. However, experience indicated that, in an ERC carrying out collaborative, focused research, the Director and thrust area leaders should meet weekly to monitor the progress of the Center and to make strategic decisions as to required changes and new directions. It rapidly became evident that this was impossible to do because there were too many thrust area leaders and the program was too fragmented. Yet the various faculty members who were serving as thrust area leaders were reluctant to give up their participation in that capacity. Consequently, the Director was faced with the challenge of restructuring the Center and reducing the number of thrust areas (and thus reducing the number of thrust area leaders) without alienating the faculty who were needed to

carry out the research agenda.

The first step was to talk with each faculty participant and convince them of the need to reduce the number of thrust areas. The alternative was to continue to struggle with too many areas and face the seemingly impossible task of giving the program focus. After the groundwork was laid for reducing the number of thrust areas, the Director next solicited the help of the Industrial Advisory Board by having them endorse and strongly support the proposal to restructure. With the help of the IAB and with the insight gained from individual discussions with the ten original thrust area leaders, the Director was able to restructure the Center in a rational way that had the support of essentially all of the participating faculty. The result was a much more manageable thrust area organizational structure which soon demonstrated its advantages for carrying out a well-focused, successful research program. The success of the new organizational structure gave faculty in the Center confidence in the Center's management and the effectiveness of the decision-making process. That confidence, in turn, made it relatively easy in subsequent years to again restructure the program as needed to enhance the Center's ability to achieve its goal. It also made it possible for the Director to terminate ineffective or non-productive projects with a minimum of turmoil.

One of the keys to the ongoing success of the ERC Program is the commitment of faculty to work together as a team to fulfill the research and educational mission of the center. This is more likely to happen when the faculty recognize the importance of collaboration and if they have confidence in the Director and in the process by which decisions are reached. Thus, it is essential that center management have credibility in the eyes of the faculty.

To facilitate the growth of an ERC and the realization of its vision, the Director should set up effective mechanisms for the intake of new people with new ideas. The survey of Directors clearly shows that center-run grant competitions are a poor mechanism for this intake; for the most part, such projects end up not aligning very well with the overall mission of the center. Because most Center Directors have actually sacrificed or heavily modified their personal research programs in favor of the center's interests, these people have both the motivation and the detachment necessary to welcome new talent into their ERCs. In most cases the Director is well advised to make the intake of new people, who are necessary for the realization of the center's vision, a very personal affair. They can be scouted, on campus or by recruitment, and their work can be steered toward the center's interests even before they are introduced to the ERC. They can then be invited to give seminars in the center's programs and/or invited to ERC retreats, to see if their fresh ideas strike a responsive note with the center as a whole. If so, they can then be brought into the center, where their presence and their new ideas allow the center to breath fresh air. (See Section 2.4, "Recruiting.")

An ERC is an excellent power base because it represents a large amount of research money, and it will attract those who are interested in wielding financial power. The Director of an ERC must make a choice as to whether s/he will become the sole power broker, the leader of a small and select coterie of power brokers, or the arbiter of power who balances the process for the good of

the center. A lesson learned from the management of research centers is that even the most promising center, founded on the most talented team of researchers, needs a constant flux of new people and new ideas to keep its edge. All centers try to stay ahead of the curve by recruiting excellent graduate students and postdocs, but very few give newly recruited faculty members senior positions with real access to center resources (especially if they are from outside the university). It is clearly NSF's intent that each individual ERC should continue as a research/ education/ technology transfer entity long after its support is terminated. The ERCs that we build must be built to last. For this reason, the Director of an ERC must resolve to build an effective faculty intake mechanism into the center (including the possibility of recruiting beyond the home university), select the new team members with exquisite care, and choose research management structures that allow the newcomers to share power and resources on an equal footing with all other participants.

It may be useful for the Director of an ERC to remain somewhat removed from matters of research management through the appointment of an Associate Director for Research and/or a research steering committee. This delegation of responsibility for the day-to-day management of research, and for the research reporting function that looms each year in the ERC Program, can leave the Director free to serve as custodian of the vision and as the chief arbitrator of the strategic plan. The research apparatus of the ERC is directed by the strategic plan. For this reason the strategic planning process is the ideal level at which new ideas should be introduced into the center's research. If the full membership of the center, including new faculty recruits and peripheral members who would like to become more integrated, have the opportunity to make meaningful contributions at the strategic planning level, the center can become a living, evolving community.

Rather than making all research management decisions personally, an ERC Director may find it more useful to maintain the vitality of the center by making sure that all ideas that serve the vision have an equal chance of implementation. It is certainly not the intent of the ERC Program to provide 11 years of high-level funding to a Director and an unchanging group of researchers, however capable and even brilliant they may be. Thus, a new Director must decide whether s/he will retain complete personal control over research management, set up a closed system of research management involving a select group of insiders, or augment the closed system with strategic planning and revitalization mechanisms that involve the whole center. Perhaps there is no choice to be made by a new Director, in the initial stages of the organization of an ERC, that will affect the center more than this pivotal decision.

2.3.2.2.2 *Education*

One of the three pillars of the ERC Program, education is the element with which most centers feel that they have had the greatest success. This success may reflect the national need for education of interdisciplinary team-oriented PhDs, more than the effective policies and programs implemented by individual ERC Directors; but in any case it is a very fertile area that may come to dominate the future of individual ERCs and even of the ERC Program itself. In recent years, the National Academies of Science and Engineering and NSF have joined with other

professional groups to rethink engineering education at all levels.[*] The impetus for this initiative is their collective alarm at the continued production of graduates at all levels who are totally untrained in team research and often openly antagonistic to industrially relevant research. The solution to this pressing problem is inherent in the ERC Program. The Program has stressed industrially oriented, interdisciplinary team research from its inception, and it has a great deal to teach the engineering science community about this urgently needed revolution in university education. Because educational policies take so long to come to fruition, it is probably wise for the Director of a new ERC to study the history of education in the Program and to make choices early in the life of the ERC that will allow this natural process to happen.

Chapter 4 presents a full treatment of ERC education programs and issues across the board. The discussion here will be limited to education issues from the standpoint of overall center management and direction.

With one partial exception, ERCs are not degree-granting academic entities. The basic responsibility for education rests with the traditional university departments; the most that an ERC can offer to the undergraduate or graduate student is an enhancement of their education. Traditional university departments are much like centrifuges, in that they apply very small force vectors to faculty and students whose interests lie near the center of the discipline that they are studying. The traditional departmental culture tends to favor students who are prepared to study classical subjects. Conversely, very large force vectors often are applied to students and faculty who venture too close to the boundaries between their nominal field and a neighboring area. The ERC culture is a boon and a refuge for these peripheral folk because it offers facilities for interdisciplinary research and the opportunity to work on research teams with people with widely different backgrounds. However, the fact remains that the ERC does not grant degrees, so that both students and faculty must be capable practitioners of their specific engineering or scientific field in order to find an intellectual base and to attain membership in a supportive community. An ERC Director must decide, very early in the life of the center, how much to coordinate with the departmental graduate programs. This coordination may be detailed, such as scheduling seminars to avoid department/ERC conflicts, or broad, such as establishing the proper balance in competing for the department's pool of graduate students; but in any case the spirit is more important than the details, and good relations are important.

Education at all levels is a lot like gardening, in that it is labor intensive and requires great patience and commitment. Hence, it is an area in which an ERC Director must delegate. There are decisions that must be made early in the life of the center that will have a considerable influence on the education program. The first of these issues is how hard the Director will press the university for contiguous space, which is discussed in more detail in Section 2.5.1.1, but

[*] See, for example: (1) National Research Council. 1995. *Engineering Education: Designing an Adaptive System.* Report of the Board on Engineering Education. Washington, DC: National Academy Press. (2) American Society for Engineering Education. 1994. *Engineering Education for a Changing World.* Washington, DC. (3) NSF. 1995. *Restructuring Engineering Education.* Arlington, VA.

which is an issue of significance for the center's education program. All Directors agree that contiguous space is highly desirable, but they disagree on the extent to which the difficulty of an ERC's being distributed throughout a university campus poses a problem. Whether or not the ERC Director becomes engaged in the university "space wars," the success of the ERC education program depends upon without collegiality among ERC students at all levels of their university experience. Whether the Director oils this process with large quantities of pizza, with a scintillating seminar program, or with nights and weekends spent in contiguous office and common lab space, the process itself is a vital catalyst. For example, when laboratory space is not contiguous with the Center, the students on an integrated project should be located in the same laboratory. In education the Director can facilitate, with a large array of imaginative policies ranging from student internships in industry to special funds for travel to conferences on relevant subjects; but s/he cannot control the basic educational process.

It is here that the ultramodern ERC structure comes up against a very successful but much more traditional institution, the university. In the middle ages, university students literally came to the university/monasteries to sit at the feet of the monks. Although today's universities are obviously advanced in ideas and practices, the fundamental model is little changed in our traditional departments, and in many universities the ERC Director who feels that s/he can interfere with this traditional educational process is in for some rude shocks. An ERC can offer large stipends and a very heady team research atmosphere, but it cannot offer the student a degree.

For this reason the Director of an ERC must realize that the center's vital crop of interdisciplinary, team-oriented, industry-friendly graduates is dependent on many factors outside of his/her direct control. If the Director chooses to be unfriendly toward the departments who have students affiliated with the center, s/he can expect the graduate committee of each of those departments to raise major difficulties about the balance their students must strike between the department and the center. If the Director is fair-minded about departmental imperatives (like obligatory teaching assistant assignments), and if both the department and the center hold the student's interests to be paramount, a mutual trust will develop that will let the ERC "thing" happen. The ERC "thing" is unique in most universities, and it involves an enriched and very challenging interdisciplinary education for a limited number of excellent students who reflect credit on both their department and the center.

In an area such as education, in which the ERC can facilitate but not dictate, the Director must exercise great care in setting up program structures. The appointment of either a part-time faculty member or a full-time professional as Education Coordinator (see Chapter 4) will greatly facilitate the recruitment and integration of both undergraduate and graduate students into the center. This person may also handle the laborious logistics of the center's seminar and internship program(s) and the educational reporting requirements of sponsors. An experienced Education Coordinator should know the students well enough to flag cases in which the student is confused and/or troubled by conflicting demands of the center and of his/her home department, or by any of the myriad problems that beset the engineering acolyte today. Because a mature ERC may involve 40-60 undergraduate and 60-80 graduate students, the Director cannot begin to involve

himself in either their personal or collective supervision. For this reason it is advisable to appoint an education committee, whose chairperson works closely with the Education Coordinator. In this way each student knows that the center provides a professional and a faculty member that they can contact with any problems, while the Education Coordinator and the rest of the committee serve the center by advising the Director on policies that affect center students. Because of the patience required, and because of the ambiguity of the relationships between the center and its allied departments, the Director may be well advised to look for a light touch when appointing members to the education committee.

While the ERC pattern does not fit precisely into the educational structure of the modern university, it may comprise its salvation. The ERC Program has pioneered interdisciplinary, team-oriented research, and it has a lot of experience in both the pitfalls and the benefits of the "new" paradigm currently being endorsed for both science and engineering education at the highest levels of national policy. This very important paradigm shift is of considerable interest to the NSF and, as the most successful of its programs in this respect, the ERC Program may see fit to base a large element of its continuity on its accomplishments in the area of education. If this assessment is correct, as the ERC moves to self-suffiency after 11 years, individual ERCs may find a very successful interdisciplinary education program to be a large factor in their continuity within their own university environments.

2.3.2.2.3 *Technology Transfer*

Technology transfer is the third pillar of the ERC Program. There are indications, based on personal contacts and our survey, that this is the element of the Program that is most variable in the extent to which Center Directors really buy in. Perhaps for this reason, there is also a wide variety of performance across the ERCs in this program element, which was so pivotal in the original funding of this program by Congress and by the National Science Foundation. Virtually all ERC Directors are academic engineers and, occasionally, academic scientists. It is axiomatic that most academics feel that technology transfer is something that they could easily do, without any special training or experience, if they could just spare time from their well-understood responsibilities in research and/or education. Perhaps it seems to many of them to be simply a matter of a few simple phone calls and of taking a little time with the industrial people who regularly beat a path to the doors of their institutions.

This perception may be the key to the inability of American science and engineering to make a real impact on American industry, and this perceived problem was a large part of the rationale for the creation of the ERC Program in 1984. The subject of Industrial Collaboration and Technology Transfer is covered at length in Chapter 5. The treatment of this topic here is from the standpoint of overall center management and direction.

The Director of a new ERC is likely to be committed to research, or s/he would not have been successful in being funded, and s/he probably has the abiding concern of the academic with educational process. However, there is no guarantee that the new Director will have the same level of commitment to technology transfer. For this reason there is an especially wide range of

choices that the Director will make in the early stages of the center's development that will affect the degree to which the center will be able to present its vision to industry for practical exploitation. At a minimum, the Director may use the academic workshop mechanism to collect a group of companies to form a paying audience in the applicable field, and then simply allocate a couple of articulate graduate students to give tours of the center in their spare time (although this approach will almost certainly fail to produce a successful industrial program.) Alternatively, the Director may designate one or more of the center PIs who are already well-connected to industry to handle company recruitment and meetings of the Industrial Advisory Board (IAB) or its analogue □ although this approach, too, is not ideal. The technology transfer area does not seem to lend itself to management by a committee, and none of the respondents to our survey reported the formation of a committee for this purpose. If the incoming Director is personally committed to the process of technology transfer □ as befits an ERC Director □ s/he will take a very active role in company recruitment (also vital to center funding), in interacting with the IAB members, and in developing opportunities for joint research with sponsoring companies. And if s/he is serious about technology transfer, s/he will also hire a Director of Technology Transfer (often called an Industrial Liaison Specialist) from outside of the academic framework, and give this employee the freedom to build meaningful relationships on an ongoing basis with companies interested in the center's technology.

The technology transfer "portfolio" really cannot be separated from the research and education elements of the center, because ERC research should be cooperative with industry and industry should play a very active role in the education of our students (e.g., through internships). Ideally, the Director should be fully committed to technology transfer, and should consider activity in this area to be integral to other activities in research and education. S/he should ensure that the directors of education and technology transfer work well together and strive to coordinate their program activities where appropriate. S/he should work very closely with the center's Director of Technology Transfer, and with people in similar positions in the university, to move center technologies directly into that part of American industry that will benefit the most. The incoming Director will have telegraphed the extent of his/her commitment to technology transfer to the new center's member companies within the first 18 months of the center's operation by the choices that s/he has made to staff and activate this vital element of the center.

2.3.2.3 Mechanisms of Delegation

Sometimes just as important as the degree to which the Director delegates responsibility within the center are the mechanism(s) of delegation. In the administrative area (Section 2.3.2.1), economy dictates that individuals be allocated specific responsibilities, such as computer networking or accounting, and then be reinforced with less trained personnel when their workloads become intolerable. An important early decision must be the type of supervision and reporting to utilize for the center administrative staff. There is clearly a limit, which is dependent on the personality and policies of the Center Director, to the number of center employees who can take detailed direction from this one source. The alternative is to have all administrative staff report through another designated individual (a Deputy Director, Executive

Director, or the Administrative Director).

This delegation should be done very carefully because its consequences for the smooth operation of the center are likely to be quite significant. Everyone involved in an ERC must realize that the whole exercise is driven by the center's vision and strategic plan. The administrative function is only an "engine" (albeit an essential one) to facilitate the realization of the vision and, as such, it will always be secondary to the program activities of the center. Whether the engine is a large 12-cylinder or a small 4-cylinder really doesn't matter, as long as the vision is realized. A simple rule of thumb is that the administrative structure of the center should always be elastic (but structured). Flexibility is also important when establishing a reporting structure, because it may be difficult to assess realistically in advance how large a staff might ultimately be in place.

In the programmatic area (Section 2.3.2.2), the three pillars of an ERC that are outlined by the Program's charter may each be best served by a different mechanism of delegation. As was noted earlier, most centers have concluded that technology transfer is best handled by a dedicated professional person, with the personal involvement of the Director and other interested PIs, because of the extent to which success in this area depends on both rapid responses and personal contacts and relationships. Most Center Directors have set up "softer" structures to guide the educational programs of their centers. Because the ERCs themselves do not usually grant degrees, a high degree of cooperation is necessary with traditional departments. Education issues are often course-specific and/or student-specific, and many call for wisdom and mature judgment while revolving primarily around the interests of the students concerned. Hundreds of hours can be spent in the resolution of these issues; therefore, in some centers an education committee with an active and very accessible chairperson may constitute the best use of faculty time, provided that most details are handled by the Education Coordinator. In other centers the Education Coordinator has more autonomy in decisionmaking about course-specific and student-specific matters, looking to the Center Director and/or an education committee for broad policy guidance.

The reporting requirements of the ERC Program review process virtually demand that each center must appoint a leader for each research thrust area and that someone, usually the Director, must combine these reports with those of the education and technology transfer programs to produce the annual report. These thrust area leaders also provide a necessary management interface between the Director and the faculty researchers, with responsibility for the detailed planning of research within that thrust. The thrust leaders, perhaps with the appointment of an overall Associate Director for Research, would seem logically to constitute an efficient committee for the planning and execution of the center's strategic research plan. To ensure the periodic introduction of new people, new ideas, and new projects, the Director may choose to create an uptake mechanism whereby the center can be revitalized. This enterprise can take many forms □ for example, a committee that emerges from a full meeting of the center (perhaps a retreat) and has the mandate of examining and possibly changing the center's strategic plan may be useful.

2.3.2.4 Principles of Delegation

Delegation of responsibilities is not an art that is peculiar to directing an ERC, and the basic principles that govern this important process are well established. Delegation should serve the personal interests of all parties involved, and it should always be voluntary within the academic context. A Director should consider the career path of all concerned, and should avoid overloading individuals or saddling young researchers with responsibilities before they are ready. Once a specific responsibility has been delegated, the Director should avoid interference or micromanagement. The Director should attempt to balance responsibilities within the ERC so that no single individual acquires excessive power and thus negatively impacts the contributions of other members of the center. People to whom responsibilities are delegated should have a clear idea of what is expected of them and of the length of time for which they are committing themselves. Most of the academics who make up the faculty of ERCs also have a base in their home departments, so that an ERC Director is really running a volunteer operation. The Director has the seductive power of his/her vision of the ERC, with certain financial resources at his/her disposal, but s/he does not have the power implicit in a direct "chain of command," so it is necessary to exercise considerable diplomacy in the process of delegation.

2.3.2.5 Continuity of Leadership

One ticklish area of delegation that should be mentioned concerns perhaps the ultimate delegation □ that of the directorship of the center. Succession is an issue that many ambitious executives, in academe as well as business, find difficult to address. If one is performing well and enjoying oneself as a Director, it is perhaps counter-instinctive to make plans to replace oneself. Nevertheless, several ERC Directors have stepped down over the years, and three have passed away □ two of them suddenly. As a responsible manager with a major investment of energy and commitment in the center, it is only prudent to provide a viable contingency plan for one's succession and thereby minimize the turbulence that would ensue in the event of the Director's departure.

Many of the centers have no such plan. Of those who have established a plan for continuity of leadership, most have appointed a Deputy Director or an Associate Director (often for Research), who will take over the leadership role until a search can be organized to select a new Director (who may or may not be the Deputy). This is an individual who routinely takes some of the Director's workload in managing aspects of center function. S/he has a seat on the Executive Council or equivalent and may have a large role in tracking and management of the center's strategic plan and/or interactions with the industrial advisory board. NSF now requires every new ERC to have this position, and some of the existing centers are following suit.

A few centers have purposely allowed the directorship to rotate among senior faculty every three to five years. They believe that this provides strength and balance in a multidisciplinary center, inasmuch as the directorship rotates among the disciplines. The practice also produces a core of seasoned talent within the center who can provide informed advice on complex or difficult issues. However, the centers that have tried this approach have found that it is not workable over the long term. The academic authority structure is already inherently weak enough without

further clouding the issue of "who's in charge?"

2.3.3 What Not to Delegate

There is general agreement among ERC Directors that the following responsibilities should not be delegated.

- Major resource allocation and budget decisions, including fiscal oversight
- Major realignment of center administrative and research structure
- Final decision on hiring (and termination of) faculty and key staff
- Final selection of companies to recruit as members
- Formal contacts with NSF to address major issues
- Policy interactions with department heads, college deans, and university top administrators
- Negotiations with university administrators for commitments of resources
- Integration of the ERC's annual report to NSF
- Responsibility for the integrity of the ERC's reporting systems.

These clearly are functions and decisions that directly affect the health and continuing success of the ERC. Missteps could be quite destabilizing. As such, responsibility for them should rest with the individual with the lead responsibility for overall center management, the Director.

2.3.4 Facilitating Cross-Disciplinary Interactions

One of the distinguishing features of the ERC Program □ an area in which it was a pioneer in contemporary academe □ is its emphasis on cross-disciplinary research. Individual ERCs have devised many ways to facilitate cross-disciplinary interactions among the faculty. In a number of centers an absolutist approach is taken: i.e., projects without cross-disciplinary interactions will not be funded through the center's resources; or else the evaluation criteria for project continuation include cross-disciplinary collaboration. In other centers the requirement is not so absolute for all projects, although there is a strong preference for cross-disciplinarity and a strong message is given that collaboration is necessary if the ERC is to be successful.

Other mechanisms that are employed to encourage and facilitate these interactions include:

- specific requests for collaborative research to meet an identified need;
- special center funds made available for cross-disciplinary projects and proposals;
- inviting researchers from a range of fields to center research meetings and retreats;
- structuring center research so that project teams cannot complete their assigned projects without obtaining assistance from other teams;
- developing a set of "end-to-end" demonstrations, within and between research clusters, that illustrate how the tools and methodologies work together; and
- engaging in design activities with center industrial affiliates (which commonly involve participants from more than one project or research thrust).

See the case study for additional suggestions.

CASE STUDY:

The Director of the Data Storage Systems Center, at Carnegie Mellon university, reports the following: "Most of our projects require cross-disciplinary work to successfully reach their goals. Many of these projects entail weekly group meetings involving faculty, research staff, and students from the various disciplines. We also have regular Center-wide seminars, which draw faculty and students from various disciplines. In the end, from my point of view, it makes no difference what department one comes from. We need a certain skill-set to accomplish our goals. The pool of faculty and students is generally (with the exception of outreach) University-wide and beyond. If I need a certain skill from a particular department, I go to the faculty member and ask if he or she is interested in having a graduate student funded by the Center. Many faculty members also come to me asking if the Center could fund them. I give each one careful consideration. To prepare the students for this cross-disciplinary work, we teach a two-day short course on the system the Center deals with, before the semester starts, to all incoming grad students. Then, in the spring semester we offer (at both the undergraduate and graduate levels) a course that has minimal prerequisites and that covers material from each of the six departments involved in the Center. Faculty from the various departments give lectures on their specialty. Such cross-disciplinary activities allow you to educate better engineers, learn something yourself as a faculty researcher, and solve problems you couldn't otherwise solve.

Directors report that the advantages of cross-disciplinary interactions include: the ability to address technical barriers that could not be overcome in any other way; intellectual challenge and stimulation; and a broader perspective available to faculty and students. The disadvantages are that: cross-disciplinary work requires more time and effort to understand the perspectives of colleagues from other disciplines; departments
sometimes do not credit such projects in promotion decisions (this is where input from the ERC Director and the support of the Dean are critical); and faculty may have trouble obtaining individual credit, which they need to obtain promotion. Thus, the disadvantages are systemic, but can be overcome, and in any event they are outweighed by the advantages of this type of research to industry and the Nation.

2.3.5 Locating the Necessary Resources

Operating a well-run ERC involves bringing together the necessary resources, including not only personnel but also facilities and funding. Facilities required to carry out the ERC□s research mission include so-called signature space for housing the center administrative offices, conference room, and general space for center-supported activities such as a computer laboratory, student library and lounge where faculty, students, and staff can gather to discuss their work. Distributed laboratory space is necessary for developing basic materials, device, and system-level competencies. Usually the Dean of the College of Engineering and the Chairs of the individual departments make the signature space available to the center. Individual

laboratory space is usually made available to faculty on a have-need basis.

Once the space is available, some remodeling is usually required. Generally these resources are obtained from indirect cost recovery (ICR) money. Equipment to outfit the space can be part of the ERC award, or acquired through any number of government equipment grants including those of NSF, or the Department of Defense, industry, DOD and philanthropic foundations.

Research management by necessity involves and revolves around available financial resources. Sources of financial support for ERC programs are many and varied, including: the primary NSF ERC award, university cost-sharing, state and industrial support, and any ERC faculty individual grants that contribute to the common pot of ERC resources. A number of ERCs receive no ICR from their host institution, while other ERCs recover a considerable amount of the indirect costs (IDCs) they generate, to use at their discretion. In the case of those ERCs receiving generous returns of their generated IDCs, some are also expected by their host institutions to subsidize a major portion (5-8 months) of the 9-month academic salary of several center-affiliated faculty members.

Industrial associates in a number of ERCs contribute to the finances of an ERC in a myriad of ways. Membership in an ERC at various levels requires a fee ranging from $1,000 to over $100,000 per year. Funds raised by these fees can be lumped into a common ERC pot; or some ERCs elect to keep industrial member fees separate from thrust area-related research. Also, in most ERCs industry can directly support a specific research endeavor, but this activity will operate independently of the thrust area work and is dependent only on its own budget. In some cases, research activities with industry require utilizing ERC resources to leverage industrial participation.

When considering the center□s funding profile, it is important to maintain balance. For example, if most of the center's funding is from NSF, then the relevance to industry is somewhat suspect. Within industry, it is best to develop a diversified portfolio of partners ranging, if possible, horizontally across various industries and vertically from raw materials producers to parts suppliers to system manufacturers. If all the outside funding is from one industry, then there is a certain vulnerability if the particular industry goes through a bad patch. A balance between state and various federal government agency and industry funding is desirable, because no one sponsor or sector has an undue influence over the activities of the ERC.

2.3.6 Avoiding Failure, Pursuing Success

There are many kinds of problems that can lead to failure for an ERC. Difficulties in leadership and management (including financial management), problems in research planning and execution (including disintegration and failure to address its vision), and failure to engage with industry positively and in the proper ways are all sources of serious trouble. These are higher-order issues that are addressed throughout this Manual. However, some problems are less programmatic in nature, and can be ameliorated to some extent by specific actions of the Director. One issue that nearly all ERC Directors cite as a serious problem is the heavy

workload placed on the Director. Regardless of the extent to which responsibilities are delegated, the Director is still almost always subject to potential burnout. One Director describes the problem as "a major flaw in the ERC concept;" even after 11 years as an ERC Director, he has found no real solution to the problem. The most prevalent approach to reducing the excessive burden on the Director is to add a Deputy or Associate Director; key staff members such as the Industrial Liaison Specialist and the Education Coordinator also remove some pressure. Several Directors point to the enormous importance of having an Operations Director or Administrative Director who is capable of handling many of the day-to-day operational tasks. Nevertheless, as one Director says, "The specter of burnout is ever-present."

Although pressures are greatest on the Director, burnout of other key personnel within an ERC is also a concern. Suggestions for alleviating this risk include the following:

- rotating standing assignments such as thrust area leadership and seminar planning;
- rotating people and responsibilities in conjunction with the university; and
- planning more thoroughly so as to reduce the number of distractions and unproductive activities.

Like failure, success is also largely a function of leadership and management, planning, and program execution. Many success factors are structural in nature; others are procedural or even attitudinal. Perhaps the best way to address these factors is to allow Center Directors to describe in their own words some of the measures that have helped their centers succeed in research, education, industrial interactions, and outreach:

"We have a clear mission that is closely linked to a well-identified, genuine industrial need."

"Our continual efforts in setting specific goals for each of the research thrusts and assessing milestones has been the most effective way to ensure success for the Center. The strategic planning mechanism is extremely important in this regard because in its full expression it integrates the Center. Goal-directed activities naturally attract industrial interest and also lead to opportunities to improve our educational offerings. From that standpoint, it is important that the Center Director has an accurate understanding of the limitations and potentials of each of the thrust areas."

"The successes of our Center in the areas of research and industrial interaction are closely intertwined which is, perhaps, one of the reasons for our success in both areas. We have focused our program on well-defined, long-term, systems-oriented goals which the industry initially doubted we could achieve but were certainly willing at least to applaud. As we progressed toward those goals, we transferred component technologies to the industry, and gradually their 'applause' was converted to serious interaction and serious financial support."

"An executive advisory board (EAB) was established to provide national guidance on strategic research direction. The EAB consists of national leaders in the field, the center director, thrust leaders, and Industrial Advisory Board officers. The national leaders were selected from government and industry organizations that represent the broad national interests in the specific

research area of the ERC."

"Our relations with industry have been key to our success. These include: the active role played by our Technical Advisory Committee, the weekly on-campus seminars by industry personnel; and the fact that we send students to conduct research at industrial sites.

"We have had considerable success recently with a new format for industrial meetings. Meetings in which we just told industry about our research were not received very enthusiastically. Instead, we are having a series of industry workshops on specific topics. We want these to be interactive workshops, so for each one we invite a limited number of key industrial people. Most of the speakers are industrial people, giving us their views of the particular topic, and some of our faculty speak as well. There is considerable time built in for discussion. An important (and time-consuming) element is writing up a report of the workshop afterwards. It is particularly useful to have a workshop on a topic or application in which the ERC has done some initial work, but where this work is not well known to industry; such a workshop can give the ERC instant visibility with industry. It should be noted that this will be positive visibility only if the workshop is run very professionally and the industry people are impressed with both the quality of the ideas and the professional management and operation of the ERC."

"Our most effective educational programs have all been related to enhancing the "systems understanding" of our students. These include short courses to incoming graduate students, summer research programs and seminars for undergraduates, 1-2 day workshops on systems design, and cross-disciplinary systems design courses at both the graduate and undergraduate levels."

"A large outreach program provides introductory contact with science for local disadvantaged school children, and leadership opportunities for the grad student mentors. Through this program we have learned to leverage our outreach activities with those of other research centers on campus to 'make a difference' in our community. The center allowed us to establish productive links with minority institutions and historically black colleges and universities."

"We have been very effective in creating an environment in which the students and faculty can participate in cross-disciplinary, team-oriented research. This kind of education allows our students to enter industry and quickly 'hit the ground running.' It produces a new breed of student, one who has a fundamental appreciation of how industry operates and who recognizes what it takes to be successful in the modern industrial world.

"We also have learned how to collaborate with other universities and industry to share resources and expertise to jointly solve problems that would be impossible for either party to solve alone.

"Finally, we have developed a unique experimental testbed that provides students with an opportunity to participate in research that is at the cutting edge of future technology

development. They have the opportunity to work on equipment that is unavailable to students anywhere else in the Nation."

An ERC represents a new type of organization in academe. At each university where a new ERC is established, the members of the ERC faculty and staff generally have to feel their way along in forming an cohesive team. Effective leadership from the Director is indispensable to this process. However, formal training in team-building and organizational interaction in this novel setting can be highly effective in speeding the development of these skills.

Rewarding center participants for strong performance is an excellent morale-booster and an incentive for further success. Many kinds of reward are available for Center Directors to bestow. One of the most prevalent and effective is continued or increased research support, including seed funding; increased compensation is of course one mechanism. Additional travel funds for making presentations at conferences can be provided out of center unrestricted funds, as well as scholarships and fellowships. Increased visibility and support for making presentations at program reviews is appreciated as a career-enhancer. Success should also, of course, lead to promotion and tenure for junior faculty in the center. Several of the centers nominate their deserving staff for university awards and undergraduates for university-sponsored project awards. (For Directors themselves, nomination to membership in the National Academy of Engineering is an appropriate form of recognition; several Directors have achieved NAE membership.) Recognition in the center newsletter and at annual meetings is an intangible but appreciated honor. One center bestows informal "citizenship" awards at center social gatherings. Finally, nothing replaces the personal recognition and appreciation expressed by the Director and other center managers for a job well done.

2.4 RECRUITING

The most powerful tool available to an ERC Director is the vital process of faculty recruiting. If we consider that this process starts with the formation of the team that will assemble the initial ERC proposal, and that it includes all subsequent new-faculty and on-campus recruiting, as well as (often) the involvement of faculty from other institutions on a project basis, the Director's role is clearly pivotal in all important aspects of the center's success. All of the "superstars" of the academic world will be on hand to watch the center (and its attractive research budget) develop, along with the workhorses and brilliant but more humble members of the university's departments. The new Director must realize that personal habits are deeply ingrained, in academe as elsewhere, and that the brilliant researcher who tends to be critical and superior in his or her attitude toward colleagues and the Department Chair will probably soon adopt the same attitude toward the center faculty and Director. Effective administration of any research enterprise calls for a careful balance between the prima donnas and the sometimes equally talented workhorses, and the new Director should carefully select those individuals who are committed to working toward the success of the center and not just toward the furtherance of their self-interest.

On the other hand, the Director must hold to his/her vision and keep the objectives of the ERC Program in mind; to do that, s/he must recruit faculty who can build a truly world-class research team. It is not essential that all center faculty also be talented in education and technology transfer, but the Director will encounter endless difficulties if his/her recruits rise to prominence in the center and then use their position to subvert these equally important center activities. Even simply ignoring education and technology transfer is injurious to the center, if many of the faculty are permitted this luxury. Perhaps the most prudent litmus test the Director can apply, throughout the process of recruiting, is to project his/her honest enthusiasm about all of the center's activities and listen very carefully for any signs of arrogance or superiority - attitudes that do not mesh well with the team culture of an ERC.

2.4.1 Recruiting for the Proposal Team

Our survey and experience have shown that the dedicated band of true believers that surrounds the prospective Director rarely survives intact to form the nucleus of the funded center. This may actually be fortunate, because a varied mix of good minds often helps to form the vision of a really exciting ERC. Such a group may well include people with different perspectives on the needs and best directions in the chosen field. For this reason, the movers and shakers who constitute the university's critical mass in the chosen research area will serve as a good platform on which the prospective Director can begin to focus and define his/her vision of the embryonic ERC.

The eventual interdisciplinary nature of the ERC will be determined largely by the strategic plan and the composition of the organizing group. If the prospective Director proposes to involve departments outside of Engineering in the ERC, s/he will be well-advised to approach Deans and Department Heads for their support before s/he attempts to recruit faculty members and graduate students into an enterprise that their own line administrators have not yet had a chance to buy into. To recruit the latter, without enlisting the support of the former, constitutes a serious threat to the career objectives of talented young people. Perhaps the rule of thumb is to make the strongest possible case, to recruit the best people, and do whatever is necessary to make sure that no damage is done to the career of anyone drawn into the orbit of the center to serve its vision.

2.4.2 Recruiting for the Initial Center Team

The Year 3 deadline looms large over the fledgling ERC. Prima donnas will fall away; real research cooperation cannot be bought; and the Director will need a significant commitment from his/her "recruits to the vision" for the process of delegation (Section 2.3.2) that will project the ERC towards success or failure. At least one, and preferably several, members of the successful organizing group should have a commitment to education or to technology transfer. NSF monitors these activities from Year 1 but, much more importantly, the full vision of the ERC Program cannot be expressed until pivotal ERC faculty embrace these parts of the vision. This is a period in which the Director must shape the initial team and aim it toward success at Year 3, but still keep his/her eye on the long-term vision for the center. This is a time of exciting expansion and the director should assess which traditional disciplines need to be represented in

the center, in order for it to achieve world leadership, and make preliminary moves toward bringing the most effective proponents of those disciplines to the campus.

It is vital to have an established research alliance and a watertight memorandum of understanding (MOU) if the allocation of research activities to affiliate institutions or PIs is to be successful and the activities are to be well-integrated with the center's educational and technology transfer mandates.

During the initial flush of the ERC's success, it is imperative that the new Director leverage the center's newly minted prestige to seed the long-term projects that, in his/her judgment, serve the center's vision. Conventional departments are looking at a minimum of 9-11 years of partial center funding for hot new faculty, and the Director is in a strong position in dealings with the university hierarchy. This is the time to staff the "long lines" of the Director's personal strategy for realizing the center's vision. This is the time to recruit, from outside and from on campus, the people that the Director sees as being necessary for success at the third-year milestone as well as the people that s/he sees as being vital to the long-term vision of the center. At this early stage of the center's development, newcomers will largely be seen as replacements for departing faculty who may not fit ideally within the ERC's vision; and the Director may find that new recruits are readily welcomed into the center.

Different approaches to recruiting are taken, depending on the ERC and its relationships with the departments involved. But some approaches are fairly standard. Usually one of the members of the Directors' executive committee is a member of the search committee in their respective departments. Center members attend the interview seminars, meet with the candidate in one-on-one discussions, and offer comments to the search committee based upon their experiences with the candidate. The decision about areas in which faculty should be hired usually remains with the individual department heads and their faculty. However, it is vital that the Center Director, as well as the participating faculty, be actively involved in the recruitment of faculty. The success of the center critically depends on the quality and interests of the faculty being recruited. Similarly, the Director and center faculty must work closely with the departments involved to ensure that the individuals recruited ultimately add value to both the center and to the department. This can be a major challenge. To make it easier, it is ideal if the center can be proactive in strategic planning with the departments with regard to mutual opportunities and responsibilities. Center administrators should try to meet regularly with Department Chairs in order to keep lines of communication open, and should make known the center's needs for faculty with particular qualifications.

In most cases, new faculty have an appointment in their respective departments but are committed to spend a substantial portion of their time (typically half) on center research projects. In some centers the ERC has taken the lead in recruiting a new faculty member, providing half a line while the department provides the other half. This is possible, of course, only if the university has dedicated faculty positions to the ERC.

It should be noted that an ERC generally can hire professionals devoted entirely to the center,

including non-faculty research staff, without a direct appointment in an academic department. Such individuals play an essential role in the management and operation of all the ERCs. Although this capability is valuable, it is important to realize that when the strategic plan changes, these individuals may not fit the new plan and must be reassigned or let go.

2.4.3 Recruiting for Years 3-9

This is the stage in the development of each ERC in which the Director must play an essential role in maintaining the center's vitality and renewing its vision. Because it is easier to write an internal justification for a portion of the ERC grant than it is to write a free-standing proposal to a very competitive granting agency, many center PIs will view with suspicion any new recruits who threaten their automatic allocation of "serious" NSF money. The Director must control the funds that support recruiting at this and all stages of the center's development, and s/he must encourage the integration of new recruits through the systematic allocation of funds to these new faculty members, enabling them to hire and support graduate students. Established PIs, many of whom will have received substantial NSF support via the ERC, should now begin to compete for at least part of their support in the "open" grants area, while new recruits should be thoroughly integrated into center research teams with thrust area funding attached.

Decisions that an ERC Director makes during this vital stage in his/her center's development will have a profound effect on success in Year 6 but, again more critically, they will determine what kind of center faces the scale-down of NSF support following Year 9. If the Director passes the Year 6 hurdle through the early recruitment of "heavy hitters" from the pure research community, s/he may eventually find that the center has made very little progress in areas of education and/or technology transfer on which the university may propose to base the center's continuity past Year 11, the final year of NSF support. In that case, the battle lines will be drawn, because the center's established research management structure will have essentially personal goals for the use of NSF funds after Year 6, while the Director will seek to perpetuate the center and his/her vision for it by bringing in new recruits, many of whom will owe their primary loyalty to the Director. If the research management structure places an appropriate value on education and technology transfer, the center may avoid dissension. But if they place too great an emphasis on their own research interests, the Director may be forced to initiate measures between Years 7 and 9 that broaden the research of the center and lead to a shared vision, so that the center is revitalized as it tackles its greatest challenge: continuity for several decades.

In the early part of this stage in the development of an ERC, it is essential that a certain attitude becomes embedded within the center. Conflicts and competitions will be inevitable as long as the center's research establishment sees the NSF grant as a pie from which each party hopes to receive a slice whose size is commensurate with his/her own perception of their talent and potential value to the center. The Director should reinforce the attitude that the center is in fact much more like a bakery in which participants can bake cooperatively a large variety and number of pies and thereby satisfy their research cravings, fostering the growth of the center while serving the center's equal interests in education and technology transfer.

2.4.4 Recruitment for the Center Continuity Team

A mature ERC represents an investment of approximately $20-$30 million in NSF funds that would otherwise probably have been spent to initiate other centers. To be favorably evaluated at the critical sixth-year milestone, a mature ERC will have achieved world leadership in its chosen field of specialization. In most mature ERCs the university, the state, and industry will have invested more than twice the NSF total of funds and all parties will have begun to see concrete accomplishments in education and technology transfer that will justify their enthusiasm and their confidence. It is at this time that the Director's recruitment activities will become both more important and more difficult.

New recruiting may become more difficult because the Director can only offer center support for tenure-track appointments in allied departments, as few academics would accept a faculty appointment exclusive to an ERC at this stage of its funding. When the university and the allied departments have formed a firm resolve to continue support for the center's educational activities, and industry has firmly decided to continue to underwrite both education and technology transfer, very creative recruiting can continue at a brisk pace. Many traditional departments in Engineering and in Science find that their faculty receive more grant support, and their students receive more job offers, if both are smoothly integrated into a mature ERC. The center may not hold together if it has become strictly a web of research alliances, but it certainly will find continuity if its education and technology transfer programs are valuable to a significant number of educational entities within the university and if industry is actively supportive. As the center matures, the Director may choose to recruit a fresh cadre of faculty with specific interests and talents in the area of team-oriented, industrially related, interdisciplinary education; this transition, however, cannot be abrupt but must be implemented in a smooth and steady fashion.

It is clear that the Director of an ERC is the keeper of the center's vision and that recruiting is his/her most effective weapon in the realization of that vision. The Director will make pivotal decisions on center administrative and research management structures, but these structures are only as good as the people that the Director can call on to staff them and make them work. If the vision articulated by the Director of an ERC inspires and sustains interest within the engineering and scientific communities, many of his/her colleagues will be interested in affiliations with the center that may range from simple exploratory visits to total commitment. This interest facilitates recruitment strategies that include the recruitment of established research faculty from the university itself, and the well orchestrated opening and filling of new faculty slots in areas that strengthen both the center and the affiliated departments. The Director may face a challenge from established center members, but the recruitment and integration of new center faculty is the key to the revitalization of the center and to the center's response to new opportunities in the field. Many centers report that an intellectual atherosclerosis results when the strategic direction of an ERC remains unchanged because of the personal research interests of established PIs; recruitment of new participants is the Director's most effective weapon in preventing this natural aging process. As the center matures, cooperative and imaginative recruiting can form the basis of excellent relationships with allied departments because win-win recruiting aligns the Center

Director's main weapon with the only real means that Deans and Department Heads have of bringing new life into their faculties or departments. Recruiting must strive for balance, as it does for excitement, and it must also serve the interests of the education and technology transfer programs that assume special importance as the center matures and plans for its continuity.

2.5 RELATIONSHIPS WITHIN THE UNIVERSITY

The establishment of an ERC constitutes a major commitment on the part of both the NSF and the host university. The center comprises a unique opportunity to reinforce a research/education/technology transfer entity within the university to the level where it becomes a world-class resource and strengthens U.S. industrial competitiveness. American universities range across a very wide spectrum in the degree to which they will really commit themselves to support individual centers, and therefore in the degree to which they will guarantee the continuity of these exciting enterprises after NSF support is terminated. Certainly, some research-intensive engineering schools play the game of "musical centers," in which centers of many kinds wax and wane and no lasting changes are made in either team research or interdisciplinary education. These schools form dozens of centers in response to changing funding opportunities, and they strip space and personnel from fading centers very rapidly in order to initiate new revenue-generating enterprises. If the university is really committed to the objectives of the ERC Program, it will become a part of the university's own strategic plan at the level of the Provost and certainly the Dean. The university administrators will make specific long-term commitments to a new ERC in terms of both space and personnel. The university will also make significant changes in curriculum, and even in departmental structures, to nurture the center as a permanent part of its revitalized programs. Research alliances come and go, but a center can become a permanent part of a university if researchers stay together because of the value added by interdisciplinary research teams and by an education predicated on cooperation between departments and in cooperation with industry.

2.5.1 Leveraging University Resources

2.5.1.1 The Issue of Contiguous Space

Perhaps no decision that the Director of an ERC will make during his/her tenure is more important than the pivotal decision to press hard for contiguous space for the center. Especially if the center embraces several traditional disciplines, it is important for its faculty members and students to be housed in contiguous space in order to develop the cohesiveness that is the life blood of an ERC. Coffee is a great catalyst, and proximity is a great facilitator; and the center will develop very differently in contiguous space. Faculty members will adopt a spectrum of arrangements that mirror the extent of their commitment to the center, in that some will have labs and offices in the center and work exclusively with center research teams, while others will retain offices and labs in their home departments and attend research team meetings and seminars in the center. But the key is that all center students will be housed in contiguous space, making the center their home on evenings and weekends, and integrating to form informal

research teams and supportive friendships that will make them profoundly different from conventionally trained students. The ERC Program has been very effective in changing the pattern of graduate education in engineering and science in many universities, and the Director must chose to commit fully to this movement or do the best s/he can with whatever space s/he can secure from the university administration.

Most agree that contiguous space is one of the main advantages that a new center can have. However, the chances of having that space allocated are directly proportional to the level of commitment of the university to the new ERC. That commitment is, in turn, influenced by the university's prior experience with research centers. If the university has built up relatively few centers, and really plans to build its research and education programs around these focused areas, it will certainly try hard to find contiguous space for an enterprise that will bring in at least $20 million in a decade. If the engineering faculty is highly research intensive, it may have developed a specialized building within which a number of research centers jockey for space in a pecking order that derives from their current and potential levels of funding. In such a situation, the new ERC should be able to find at least sufficient space for central administrative offices and lab space for specialized equipment that is central to its mission. However, engineering faculties in heavily endowed universities are commonly very short of space, so the new ERC may be forced to be a "virtual" center that exists in the common will of its participants and in the vision of its Director, but whose physical being is a distributed network of office, laboratories, and personal connected by electronic linkages.

In the view of the authors, the research and technology transfer functions of an ERC can (with some difficulty) be properly exercised without contiguous space, but the education function may be compromised. A joint committee of the National Academies of Science and Engineering has correctly characterized the graduate student, especially in the physical sciences, as a "natural loner."[*] This individualistic tendency among students can be partially corrected by seminar programs in which center research is discussed; but the more peripheral students still will leave the room with only the vaguest concept of the center to which they belong. It is essential to ensure that all ERC students understand clearly the mission and goals of the center and how they relate to the way things are done in the center. This is important not only for the students but also for the center itself. Nothing is more deadly than the perception by a site visit team that the students have no idea what the center is all about.

Real integration into interdisciplinary research teams occurs best in common lab space, and real bonding most often occurs when undergraduate and graduate students occupy contiguous space and develop the *esprit de corps* that comes with sharing bad coffee and long hours. Hallways lined with center posters and echoing with spontaneous birthday parties for center students, group meals, poster sessions, and other social/academic gatherings are often the heart of a truly effective ERC education program. Most of the ERCs have a "Student Council" or comparable

[*] COSEPUP. 1995. Reshaping the graduate education of scientists and engineers. Committee on Science, Engineering, and Public Policy. National Academies of Science and Engineering. Washington, DC: National Academy Press.

organization that facilitates interaction and a sense of common purpose among the students.

2.5.1.2 Direct Financial Support

Across the Program, about 10% of the annual budget of ERCs comes from universities. Most ERCs have been able to obtain substantial financial commitments from their host university, including annual support in addition to new faculty positions. For the ERC at NCSU, for example, this annual support package has included equipment support, salary support for students and research staff, operating costs, and laboratory upfitting costs. The University of Maryland's ERC began life as the Systems Research Center, but in its seventh year was able to persuade the university and the State of Maryland of the importance of the ERC for the interests of both, and that they should endow the ERC as the Institute for Systems Research, with permanent funding (i.e., as a line item in the State's budget).

At Carnegie Mellon's DSSC, the university has committed to substantial cost-sharing on capital equipment □ something the Director terms "very effective," since capital equipment is typically very hard to obtain at a university. University cost-sharing is often flexible in use, and carries no indirect cost burden. Several of the ERCs have had new buildings constructed for the center, using funds provided partly by the university and in large part by the state. A dedicated building and/or state-of-the-art equipment and facilities make recruiting of faculty and graduate students easier, and also improve the attractiveness of the center to industry and funding agencies. A few ERCs have developed world-class experimental facilities for use by the center faculty and others; the funds have come from the university and the state government.

2.5.2 Relationships Within the University Hierarchy

In any major research-intensive university, the senior administration of a successful Engineering College is confronted almost daily with demands for support of specific programs by forceful proponents. The Director of a new ERC must present his/her vision of the center persuasively enough that the Engineering Dean and the university's Provost and Vice-President for Research, who are rarely both engineers or even scientists, buy in to the vision to the exclusion of distracting demands. The concept of the ERC is inherently exciting, and the objectives of an ERC are unique, but the center will not thrive if it does not capture the strong support and commitment of the university's senior administration.

To engender that support, it is imperative that the ERC be recognized throughout the university community as being on a plane of intellectual and scholastic excellence that equals or exceeds any other research unit at the university. Even 10 years after it is established, the center's accomplishments in research and education should loom large in the university's own public assessment of its strengths. If the ERC does not dominate the internal priorities and self-image of the university, no amount of NSF planning and/or support will guarantee its continuity as an effective unit when it "graduates" from NSF support.

The Dean of Engineering must be willing to commit space and faculty slots to the nascent center.

This individual in particular must be a dedicated supporter of the center. The Dean can be invaluable to the ERC and its Director as a facilitator, a "fixer," and an all-around strengthener of the center within the university. A few ERCs have had a Dean of Engineering as their Director; in other cases, ERC Directors have been promoted to Dean. The best relationship here is a close and supportive one. To that end, the Director should not hold himself aloof from such college functions as Parent's Day or alumni functions, because loyalties and goodwill are bidirectional.

The support of other senior administrators is also vital. The Provost must be willing to reinforce the College of Engineering with funding for new faculty slots and with approval for new programs, and he/she should see the center as an excellent model and an effective catalyst for interdisciplinary team research. The Provost and the Dean of Graduate Studies should be proactive in support of the acceptability of thesis work done on center research terms. The Vice-President for Research should help in the acquisition of contiguous space for the center, and he/she should support the center financially by helping to secure state funding and by returning a proportion of the indirect costs (IDCs) on center grants.

Eventually, the Vice-President for Research should be so impressed by the center's success in team research, interdisciplinary education, and technology transfer that he/she will be willing to commit significant portions of his/her disposable income to the establishment of additional *de facto* centers, even outside of engineering. The ERC Program can really benefit a university if its senior administration become believers in the process, as they win and then run an ERC, so that the ERC ideas are "cloned" and expressed in other areas in which the institution has a critical mass of talent and experience. Public land-grant universities vastly outnumber heavily endowed private universities in the United States. For this reason, changes brought about as a result of ERCs in the public institutions may ramify to produce huge changes in national research and education policies, if the top university administrations capture the essential vision of the ERC Program.

2.5.3 Relationships with University Departments

An individual ERC may involve between 2 and 12 different departments, and people from 2-4 different faculties may be among its participants. The Director of an ERC must realize that the departments are the continuing administrative entities of the university. Most center faculty will hold tenured or tenure-track positions in conventional departments, and virtually all graduate students will actually be registered in these departments. (Indeed, the support that departments provide to an ERC often appears to be roughly proportional to the number of their faculty and students that it supports.) Departments offer center-specific courses and share in the costs of equipment. A center cannot succeed without the support of departments, but it is a difficult relationship that must constantly be nurtured. Department Heads come and go, but the ERC Director must continuously persuade the power brokers of key departments that the center enlarges their research horizons and enhances their students' education.

What is really needed is very strong leadership from the Dean (and higher university administrators) to make everyone involved understand that working in a positive manner with

the center is in the interest of the departments. In particularly enlightened departments, the Center Director may even receive kudos for effective contacts with industry.

Many of the real problems that will challenge an ERC Director will involve affiliated departments directly, and the Director simply cannot afford to ignore this critical academic interface. Some departments will be only distantly related to the center, but normally two to six will be intimately involved. Divisive issues will include department faculty who "disappear" into the center and then expect recognition within the department for ERC-related accomplishments that most department faculty may not even know about. Similarly, in some cases there may be graduate students who are recruited by the department and then disappear into the center space and center activities, only to reappear three to four years later expecting an advanced graduate degree from their "home department." ERCs are powerful, in terms of funding and the inherent appeal of their vision, and they can engender resentments in allied departments that may surface and confront the unwary ERC Director when s/he least expects it. (In one ERC the chairman of a key department once refused to attend a critical NSF site visit because of unresolved problems between his department and the center.)

These are potentially serious problems, but they can be avoided by a perceptive and personable ERC Director. Regular meetings with the heads of affiliated departments can help both parties to "flag" faculty and student problems before they become too serious. Faculty slots that are allocated to the ERC should be filled in a way that benefits both the center and the department concerned. The Director should work with the departments to ensure that the filling of these slots not only benefits the center, but also contributes to the long-term interests of the department. The ERC Director should apprise the Department Head of plans for increased research activity that will draw specific faculty away from teaching responsibilities, so that alternate plans can be made in a timely fashion. There is no reason why a Department Head should be alerted at the last minute about demands for either "teaching relief" or other special concessions related to the research activities of ERC-related faculty. The ERC Director should submit a written assessment of the performance of each faculty member to his/her Department Head, in ample time for its inclusion in the department's annual report.

The issue of promotion and tenure deserves special attention. Promotion and tenure decisions are made in the departments, and any animosity felt toward the ERC can easily be objectified in adverse promotion and tenure decisions regarding center junior faculty. In addition, the possible adverse evaluation of team research and multi-authored papers has been a point of uncertainty for many faculty and students considering participation in an ERC. However, the survey of ERC Directors showed no such experiences. In most cases, there is considerable collegial interaction on these matters between the departments and the center. Generally, the Director and/or senior center faculty provide departments with letters of assessment and/or support for candidates. In many cases, senior center faculty hold positions on the departmental review committees and college committees, where they have the same privileges as faculty from the departments. In certain instances, it is reported, the input of the Center Director has been the deciding factor in a positive promotion outcome. More than one Director related that participation in the center is viewed as favorable, not unfavorable, for promotion and tenure. Even in the few cases where the

center has no direct influence on departmental and college review committees, the outcomes have been favorable.

Actually, this is not surprising, since the emphasis of ERCs on goal-oriented research, publication and interaction with other faculty, and excellence in teaching all mesh well with the concept of academic advancement. As one Director noted: "It is entirely appropriate for an ERC to play a role in promotion and tenure decisions. Unless the case can be made that participation in the center is beneficial not only to the center but also to the department, there will not be a culture change on campus recognizing the importance of center-related cross-disciplinary research." The Director has a key role and responsibility for ensuring that s/he helps those who are dedicated to the center's programs to achieve their professional goals and deserved rewards.

The ERC should cooperate with allied departments in the recruitment of graduate students, and the ERC Director should pay special attention to the composition of the advisory committee for center graduate students. In the simplest case, the student's thesis advisor will be a member of his/her host department and other members of the advisory committee will also belong to that department. In other cases, a graduate student may be supervised by an advisor from outside his/her home department and the advisory committee may be a smorgasbord. Especially in this latter case, it may be important to have the student give regular seminars in the home department, in addition to center seminars (they require no additional preparation), so that departmental people are not blind-sided by the final thesis. If the vision of the ERC is truly innovative and really addresses the cutting edge in the field, the student's thesis may well seem like fantasy or heresy to members of the home department, and departmental faculty should have adequate opportunity to get used to these new concepts.

Good relationships with allied university departments should be effortless and natural, and they are vital in the solution of many of the problems noted by Directors (such as faculty recognition and student integration). For example, attending meetings of Department Heads called by the Dean may strike the new ERC Director as a waste of time, because many issues may not really involve the center. However, regular attendance builds good relationships and common interests and reassures the Dean and the Department Heads that the talented Director of this "hot" research unit, the ERC, views himself as just another member, like themselves, of the university leadership community.

2.6 RELATIONSHIPS OUTSIDE THE UNIVERSITY

2.6.1 The Strategic Relationship With Industry

One of the first lessons that a new Director learns, as s/he begins to get involved in technology transfer, is that there is a spectrum of different forms of potential interaction between any company and any academic entity. In the most academic form, the most research-oriented of the company's employees will attend IAB meetings to hear papers and see posters in the best

academic tradition, much as they would attend meetings of the learned societies to which they belong. These people and their research units are often overworked or understaffed. They will persuade their companies to seek short-term, highly focused assistance from the center for small projects, assuming that their corporate-level managers can justify the annual expenses of membership and travel. Experience indicates that there will always be a high rate of turnover of these more "academic" relationships.

The next level of relationship commonly found in ERCs, begins to involve the upper-level managers who are responsible for research management and strategic planning in their companies. When they come to respect the technology transfer capabilities of the center, they often will propose joint research projects that may be funded by themselves, by a consortium of companies in that area, or by a third party (commonly a federal mission agency). These contracts are very lucrative; often they mesh well with the strategic plan of the center; and they cement the relationship between the center and the cooperative company or companies. These cooperative contracts allow the sponsoring company to see the center and its students in a very positive light and, especially if students have been specifically mentored by the company or placed in industrial internships, the company often will hire center students.

Perhaps the highest form of relationship that may develop between an ERC and a company is one in which the ERC actually becomes part of the company's strategic planning process, in what may be called a "strategic partnership." Several ERCs have developed longstanding relationships of this type. (See the case study for one example.) In a variation on this theme, many ERCs have spun off companies which have then become center partners. All the centers have transferred technologies to industry in one form or another; one has transferred 27 new technologies to its related industries. A few centers maintain the less intensive "academic interactions" type of relationship. There is perhaps no other facet of ERC organization that reflects the personal predilections of the Director more transparently than the structures that s/he has set up to accomplish technology transfer. Some excerpts from the survey of Directors may serve to illustrate this point.

"To more tightly couple industry and the university, two mechanisms have recently been implemented. First, specific faculty members have been assigned to ensure the satisfaction of specific member companies. These faculty members are encouraged to visit their assigned company often, understand the company's business and products, outline the company's technology transfer expectations, and facilitate communication with the university. Second, the Center has asked each industry sponsor to "mentor" one or more research projects. This provides a tight coupling between faculty/students and industry for the project, and facilitates technology transfer."

"We do everything we can think of to interact with industry. The most effective mechanism is cooperative research, where we and they work jointly on a project and have interdependence. Such projects rarely die, and in fact typically lead to new, related projects and more support."

"Generally, when we ask industry for recommendations, we get back the response to 'keep doing

what you are doing.' We have to be very focused on the questions of interest to bring out the trade-offs. We have to create the draft and the issues ourselves with which to start the feedback process."

"Industry is the primary customer for our research and our students. There is no major problem in working with them that is worth highlighting. On the other hand, there are myriads of small problems that must be navigated through on a daily basis, including means of handling their desire to keep information proprietary, patent rights, etc. A well-thought-out and consistent means of dealing with all these issues must be established early."

The close interactions of ERCs with their industry technical advisory committees have not only been highly effective in guiding the centers' plans and research; they also have taught the need for flexibility in interactions with industry. Industry doesn't speak with one voice; each company has different needs and priorities. It is essential that both parties have realistic expectations concerning the prospective interaction, in order to avoid disappointment. New NSF guidance requires that each ERC's IAB carry out a "SWOT" (Strengths, Weaknesses, Opportunities, and Threats) analysis each year to strengthen the ERC and provide feedback to NSF review teams (see 5.2.4). Beginning indications are that this process helps develop a more collective partnership in the ERC.

Another nearly universal finding is that personal interactions work best. For example, students spending time doing research at industry sites have fostered strong relationships with their industry hosts. Persuading industry personnel to visit an ERC even briefly (e.g., for one-day seminar visits) invariably brings surprised and highly positive reactions to what the center is accomplishing.

CASE STUDY:
The Data Storage Systems Center, at Carnegie Mellon University, began as a totally industry-funded center with several million dollars in funding. Initially, the industry was so delighted to have a university involved in this area that they put almost no restrictions on how the money was used. Later, as the DSSC became more sophisticated in its research and as profit margins for the industry declined, industry attached more and more "strings" on how the money was to be used. The Center's Director became a broker for industrial research projects for Center faculty, and although the research was cross-disciplinary and all the technologies involved in data storage systems were being addressed, because each company had different objectives there was no systems-oriented focus. The ERC award was then sought and won, and with the NSF funding, long-range, systems-oriented goals were defined and pursued. Ultimately, the Center helped guide the industry into forming a National Storage Industry Consortium (NSIC), which helps to coordinate the long-term precompetitive research of all its industrial members as well as all the universities working in this area. In 1996, NSIC was involved in over $50 million in research. The DSSC has actively done everything it could to support the consortium, even though a large part of NSIC funding has gone to other universities. The NSIC has helped the industry grow and speak loudly with one voice, which in the end has produced more funding and influence for the DSSC. The Director of the DSSC has now been asked to serve as the technical manager for the

main research program that NSIC sponsors.

2.6.2 Outreach To (and Alliances With) Other Institutions

Outreach to other institutions for research and education is one of the goals of the ERC Program, which hopes by this means to disseminate more rapidly and widely the "ERC culture." It is accomplished through a variety of mechanisms, including joint proposals, exchange of faculty and/or students, direct funding for specific research tasks, consulting activities, and other means. The goal is worthy, and in fact the results of these interactions have largely been worthwhile. However, some lessons have been learned in the course of pursuing them.

First, it is essential to identify concrete reasons for pursuing an outreach activity with another institution. Successful alliances can be established only when both parties benefit from the collaboration. Second, it is necessary to identify those institutions that have capabilities and facilities that are complementary to the ERC's. In this way the interaction becomes a win-win collaboration that benefits both sides. Third, discussion among the ERC thrust area leaders should identify the appropriate individual to contact at the other institution. The approach is then made and, if there is an interest, joint discussions are held to ensure that the outreach institution participant(s) have the same goals and are willing to follow the procedures used in the ERC. It is important to ensure that there is a strong intellectual match-up. Experience demonstrates that financial support alone is not a sufficient basis for a strong partnership.

It must be realized that failures can occur. Therefore, it should be made clear at the outset that, if the interaction is not successful, the alliance will be terminated.

2.7 LIFE AFTER NSF

The immediate success of a new or prospective ERC depends heavily on the extent to which the Director's vision engages the ERC's team, the university, and industry and also satisfies the NSF Directorate and its site visitors. The short-range continuity of an ERC depends equally heavily on the Director's success in continuously revitalizing the center through the real integration of new faculty from within and outside the university. The long-range success of the center will depend entirely on the extent to which the continuing partners the university and industry value what the center has accomplished in interdisciplinary education and team-based research.

Research alliances are essentially ephemeral things. They shift with changing research interests and they succeed in a direct relationship with their success in attracting external funding which suppresses the "lone ranger" tendencies of talented prima donnas. They may inspire but they do not educate students. They attract industry but they do not make common purpose with industrial partners. The long-range continuity of an ERC, which is NSF's objective for each ERC, depends on effecting a cultural and structural change in the university and a real and mutual interdependence with industry. Perhaps an ERC Director will be judged, at the end of the day, on the extent to which s/he has really embedded the center into the functional fabric of the

university and into the machinery and the bottom line of industry.

The basic structure of the university has not changed a great deal since the Middle Ages. The university as a concept has survived and thrived because its scholars, arrayed in units of specialization known as departments, can educate students. Research and knowledge acquisition happen in many different frameworks, but formal education occurs in the departmental framework of the university. Strong departments are simultaneously the friends and the enemies of effective graduate education. A strong department of Electrical Engineering or of Physics, for example, provides its acolytes with increasingly specialized and theoretical knowledge of esoteric fields. However, policy-oriented bodies such as the National Academies of Science and Engineering have taken the pulse of industry and of the country and concluded that we need a new paradigm in graduate education, which the ERCs clearly embody. If the Provost, Vice-President of Research, Deans, and Department Heads of a university see an ERC as a successful exercise in interdisciplinary education in an area in which they have world leadership, they have the resources to guarantee its long-range continuity. The Provost has faculty slots, the Vice President has IDC funds, the Dean has control over space, and the departments have students. After Year 3, and certainly after Year 6, the long-range prospects of the center depend much more on the extent to which the ERC's vision has been embraced by the university and the faculty than it does on the evaluation of the ERC by NSF's ERC Program management.

The center's relationship with industry is an equally important component in its long-range continuity, and in its effectiveness in giving substance to its vision. Today's "leaner" companies cannot afford large, esoteric, and unfocused research groups □ any more than they can afford to send their people to yet another set of dry academic seminars. However, the fact remains that most of the ground-breaking research on which modern industries are based was and is conducted in universities. The ERC that successfully makes the connection between university-based research and real industrial needs may outlive most of its faculty. A strong ERC will spin off companies with a real chance for survival and/or it will integrate itself into the planning process of companies to form functional strategic partnerships. The Director and the ERC team must have built a broader and deeper contact with industry, one that is fully and functionally connected to the center's education program, if the ERC is to rely on the not-inconsiderable financial resources of industry to ensure the center's long-range continuity.

Education and technology transfer both are inherently long-range undertakings, and they are optimally combined in the ERC Program mandates. Many of the ERCs already are valued very highly by industry because they focus university research at a point where industry can grasp and exploit it, and because they produce a steady steam of uniquely cross-trained, team-oriented graduates who are likely to eclipse their peers in creativity and productivity. There is enough potential at the industrial interface to "power" a center indefinitely, and without NSF funding, but the Director must harness the educational support of the university to preserve the essential strengths and distinctions of an ERC.

The key to surviving and thriving after NSF funding ceases may well be to begin planning early □ ideally in Years 4-6 □ for self-sufficiency. In order to continue the type of culture that the

ERC has engendered, it will be necessary to maintain at least the essential elements of the center's infrastructure. As funding tightens, the "refinements" □ features such as services (e.g., analysis and demonstrations), shared facilities upkeep, education programs, seminars, etc., that help define the special nature of an ERC □ will come under scrutiny as luxuries. Some form of these infrastructure elements will need to be adopted and perpetuated by the university (not industry, as this is part of the university's mission).

There are at least three issues that need to be resolved before an ERC graduates from NSF funding to self-sufficiency. These issues include: funding, space, and administrative position. In the best of cases, it may take a year or more to negotiate a permanent position for an ERC in the permanent university structure. Since resources may be controlled by several different levels in the university (e.g., the Dean and upper administration), there are several negotiations that must successfully be navigated. In addition, with the tendency for shrinking average time in office (it has been noted that the average time in office of a university president today is about five years), chances are the initial agreement may have to be renegotiated one or two times before a stable, long-term agreement is reached. The ERC requires a plan and positive leadership during this period to maintain high moral with the Center faculty moving forward together. Whatever the agreement, get the arrangements in writing. Verbal agreements are easily misunderstood.

Funding. Universities have different ways of creating discretionary funds. These include return on overhead, interest on money in university accounts, return on tuition, gifts, and income from technology licenses. If given a formula, the ERC can directly influence the income from the first three sources by generating more contracts, banking more discretionary funds, and admitting more students. On these first three, projections can be made and a budget established accurate enough for planning purposes. The latter two categories should not be depended upon for on-going operational expenses. Many universities are familiar with the departmental structure, which is essentially a "no growth" or "slow growth" organization. Budgets may be fixed more or less from year to year. It is important for ERCs to have an incentive-based funding. They need to provide equipment and infrastructure for new projects and new domains. They need to generate seed funding to start new ideas that can eventually mature into self-sustaining multidisciplinary research projects. Yet another issue is "who gets credit" for bringing in the funding. As a multidisciplinary research center with faculty from Engineering and other departments, there should be no tension in determining which department a faculty member initiates a research proposal through. A simple rule applied at some centers is that if the proposal has faculty from multiple departments as Principle Investigators who are part of the ERC, then the ERC is the appropriate organization to receive credit for that proposal.

Space. The first issue is to guarantee that the space the center currently occupies will remain theirs. Since space planning often occurs five or more years prior to physical occupancy, it is important for ERCs to understand what will happen with their space once they transition. In addition, the ERC needs to determine the space allocation process so that new space can be acquired as the ERC grows.

Administration. It is important to establish where in the university hierarchy the ERC Director

will continue to report. This has a direct impact on strategic planning and promotion of Center personnel. It is important that center personnel sit on both the faculty and administration promotion committees to represent the unique perspective of multidisciplinary research. Center Directors can educate their colleagues on these committees as well as ensure steady advancement for personnel involved in the ERC. In addition, the ERC should be an integral part of the administrative strategic planning process, not only to ensure stability for the ERC but also to inject new perspectives into the strategic planning process.

It is crucial to begin early building a case for this eventuality within the university. All participants in the center, not just the Director, should be involved. The industrial liaison specialist should become involved with the university's technology transfer people by sharing information, experience, and resources. There are many ways that the education coordinator could share resources with the existing units on campus and make it known. The AD continuously works as a liaison with the university's administrative network and, while constantly compromising to accomplish things, is able to air the center's perspective. If the center has found a better way to do something, share it. At every opportunity, center participants should get others within the university on their side so they would be missed if they weren't there. Everyone has a chance to make themselves indispensable by becoming actively involved in campus activities. Always think beyond the center!

The university has to be reminded constantly of what the center is accomplishing, with the emphasis being on why it is important. Sell the ideal, not the Center. (For example, emphasize that center graduates are very employable because they have interdisciplinary training and can work in teams.) Centers gather a lot of data; probably no other unit on campus has as much tracking information as the ERC does. Share these statistics with the university early and often; the university may become dependent upon it and want to maintain the center's infrastructure partly in order to continue gathering it.

Again, the concept is that of marketing the ideals upon which the center is founded, as opposed to marketing the center itself. If the culture of a particular center becomes too closely identified with the NSF ERC Program, it will die when the NSF funding stops. Therefore the real challenge is to create and continuously showcase a set of values that will be embraced by the center's continuing partners. A center might consider creating a position for a marketing manager. In the short term, these individuals would market the Center itself (through publicity, contacts, recruitment, etc.). But for the long term they would market the ideals and identify opportunities to illustrate how the Center has served as a demonstration vehicle to accomplish those ideals and how the university could build upon that experience.

2.8 SUMMARY

As was noted at the beginning of this chapter, the job of directing an ERC is all about choices. No one should choose this powerful and prestigious position if s/he is not fully committed to the stated objectives of the ERC Program and to its values of team-oriented, industrially relevant,

interdisciplinary research. The Director of a new ERC must choose the extent to which s/he will delegate and the areas over which s/he will retain effective control. Choices also are implicit in the assembly of the team that will apply for the ERC, and of the teams that will run the center at all stages of its development. A balance of research talent and commitment to the center's vision is essential, and interdisciplinary education and technology transfer will not reach their full potential unless the Director chooses his/her teams wisely. It is naive to expect that every center faculty member will excel in all center activities, but a subset must be capable of world-class work in each of the major areas of research, education, and technology transfer.

Within the university framework, an ERC Director must chose his/her style of interaction. A measure of persuasion and firmness may be necessary to obtain contiguous space, at the outset, and to take full advantage of the university's pledges of support for the center. As the center matures and begins to concentrate on the continuity of its research, education, and technology transfer programs, cooperative relationships with allied departments and the appropriate parts of the university hierarchy come to the fore. Mutually beneficial recruitment is the Director's most potent asset in this matter and a confrontational approach by a mature center may leave it surrounded by enemies at a time when it most needs friends. It is the stated intent of the ERC Program that the centers should make lasting changes in university education and also sharply improve the competitiveness of American industry; and most ERCs actually accomplish these objectives. Clever recruitment and excellent relationships within the university can extrapolate these changes by passing the center's vision to the university departments and faculties that constitute the operative research-education-technology transfer mechanism of our university system.

In summary: Be faithful to your vision; articulate your vision to draw together a team of like-minded colleagues; keep the dream fresh by adding new people who can move with the field; and "May the Force be with you!"

ATTACHMENT 2-1
PROFILE OF AN "IDEAL" ERC DIRECTOR

Based on the experience of a dozen years and more than 25 Engineering Research Centers, it has become evident to NSF ERC Program Directors that certain characteristics of background, ability, and personality tend to be associated with success in directing an ERC. This is not to say that NSF perceives a fixed "model" of the ideal ERC Director. Certainly there is a range of characteristics and any given individual will be stronger in some areas than in others. In addition, the "ideal" profile will vary across different fields, universities, and industry bases. Finally, there are all the intangibles of team chemistry, timing, and luck that may play as significant a role as any other more objective factor in one's ability to lead an ERC effectively.

Nevertheless, having expressed these caveats, it is worthwhile to describe some of the likely success factors for an ERC Director, as identified in an informal survey of current and past NSF ERC PDs.

With regard to professional background, the individual will certainly possess the PhD degree in a relevant field of engineering or science. S/he will be a university professor. Experience in working with industry is definitely a plus for an ERC Director. If a Director comes to the university from industry to lead the ERC, it can be problematical if s/he expects to use a more "directive" style of management at the university. In any case, some management experience is highly recommended.

The Director will be a tenured professor who is likely to have achieved widespread recognition in his or her field for scholarly and intellectual attainments. Age is not a factor; the person can be at early, mid, or late career, as long as he/she is tenured.

In terms of leadership ability, five very important traits can be identified: 1) the ability to articulate a vision for the ERC that is shared with industry and the faculty and that is flexible enough to evolve over time with the developments of the ERC and the field; 2) a clear perception of the current status of the field and a vision of future advancements and a strategy to achieve them; 3) the ability to think at the systems level and integrate research from different fields to achieve a systems-level goal; 4) the ability to recognize intellectual needs and identify needed talents, both internal and external to the university faculty and form and sustain a cross-disciplinary team over time; and 5) the ability to lead without coercion. A Director will probably be someone who prefers to deal with the "big picture," rather than with details, and who knows how to hire and delegate the detailed tasks. It is also quite useful if the individual is a skilled ÒsalesmanÓ in representing the center's needs and capabilities to potential sponsors in industry and government, as well as within the university. Again, the ability to articulate the vision of the ERC and energize people to share in the vision for the ERC and its development is critical.

To that end, interpersonal skills that involve team building are valuable. Management in an academic environment is often a delicate operation, so it is strongly advisable that the Director be diplomatic, tactful, and empathetic as well as perceptive, alert, and determined. Given the

enormous demands of the job and the personal self-sacrifices it entails, the ability to make a total commitment to the center is vital.

The prospective Director must have gathered together a group of colleagues and junior faculty in relevant fields who are willing to form the core of the ERC faculty team. It is also very important to have an industrial support base (or at least strong contacts) established through consulting, participation in a previous center, industry employment, etc. It is useful if the individual has good relations with the university and departmental administrators, although these relationships can be built after the center is established. Also valuable are other federal, state, and private support bases (e.g., foundations) beyond NSF.

The Director should understand the opportunity the ERC provides to change the educational/research culture of the engineering efforts of the university and the potential to impact beyond engineering. H/she should be interested in integrating the results of the ERCs systems perspective into the curriculum in new and innovative ways.

Finally, in terms of attitudes and personal orientation, an ERC Director should be a team-oriented coalition-builder who welcomes change, since technological and "cultural" change are what the ERCs are all about. The person's attitude toward the encouragement of women and underrepresented minorities to pursue engineering education and research must be genuinely positive. S/he should be oriented toward focused basic research that integrates science and engineering with long-term benefits for industry, because this is the fundamental rationale for the ERC Program. Finally, the Director should be oriented always toward achieving a center in which the integrated whole is greater than the sum of its individual parts.

ATTACHMENT 2-2
WORKING GROUP #1 (DIRECTORS) QUESTIONNAIRE

1. Vision:
    (a) How is the vision established in your Center?
    (b) Is the vision updated on a regular basis? If so, who participates?

2. How are decisions arrived at regarding (list advantages and disadvantages in each area):
    (a) policy issues
    (b) establishment of research goals
    (c) termination of old projects and establishment of new ones
    (d) budget/resource allocations.

3. How do you revitalize the Center on a continuing basis?

4. What role has the Center and/or Director played in recruiting new faculty to the university?

5. What role has the Center played in promotion and tenure decisions?

6. How do departments participate in facilitating the success of the Center?

7. What effective ways have you found to leverage resources from the university?

8. What have you done to facilitate cross-disciplinary interactions within the Center?

9. How do you reward success in the Center?

10. How do you structure successful alliances or outreach activities with other institutions?

11. Is your Center located in contiguous space or is it "distributed"? If distributed, how do you meet the objective of an integrated/focused program?

12. What steps have you taken to distribute the work load and avoid burnout?

13. Is there a strategy in place to identify a successor to the director and to provide continuity of leadership if the director were to leave?

14. What effect has the responsibilities of being director had on your individual research?

15. Describe how your center balances the requirements of individual PhD dissertation research with the need for students to also provide services to other students and/or participate in the maintenance and repair of equipment, etc.,

16. What impact has your Center had on educational programs? (new courses, new degree

programs, etc.)

17. What are your mechanisms for interacting with industry?

18. How have your interactions with industry evolved over the years?

19. How do you identify potential new partners from industry and establish interactions with them on a "proper" basis?

20. How do you manage Intellectual Property Rights issues when funding for the center comes from several different sources?

21. What is the nature of your "testbed" and how does industry interface with it or benefit from it?

22. What role should ERCs play in promoting/supporting local and state economies?

23. Describe those efforts that have been especially effective in facilitating the success of the Center in research, education, industry interaction, and outreach.