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SECOND YEAR REPORT

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EXECUTIVE SUMMARY

This report describes the results of the first and second years of an ongoing descriptive study of the transition to self-sufficiency for mature Engineering Research Centers (ERCs), their progress in achieving that goal once base support from the National Science Foundation (NSF) ceases, and the impact of the paths taken toward self-sufficiency on the ERC culture attained under NSF support. NSF policy is based on the expectation that, by the end of the eleven-year ERC cooperative agreement, Centers will “graduate” from the program and become self-sustaining entities, unless they compete successfully for a new ERC award with a significantly different focus. NSF requested that the study be concerned not just with the survival of ERCs as economically viable entities – there are literally hundreds of centers in universities today – but with their survival *distinctly as ERCs*. The key questions are which critical programmatic characteristics of an ERC remain intact, the extent to which they remain intact, and, ultimately, why they do or do not remain intact.

The ERC Program was designed to develop long-term partnerships between universities and industry, create knowledge and technology to advance next-generation engineered systems, and prepare a new generation of engineering leaders who are more capable of engaging successfully in team-based, cross-disciplinary engineering practice. Individual ERCs provide an integrated environment for academe and industry to focus on next-generation advances in complex engineered systems important for the Nation’s future. From NSF’s perspective, key characteristics of an ERC might be characterized as follows:

- An engineered systems focus and strategic planning drives an ERC’s research;
- An ERC’s general organizing principle assumes total integration of research, education, and industry;
- ERCs are interdisciplinary: the engineered systems work has yielded an integration of disciplines;
- Undergraduate as well as graduate students participate in cross-disciplinary research teams and systems-level activities in ERCs;
- ERCs enhance curriculum and degree programs on the campus;
- ERCs have a strong level of financial commitment by companies and industry representatives;
- ERCs have university commitment to their continuation.

The first year study was based on a series of confidential interviews conducted in 1997 by the Science and Technology Policy Program of SRI International with a wide range of individuals associated with twelve ERCs that had reached or were nearing their eleventh year of NSF ERC Program support. Additional interviews were conducted with these and four additional Centers that were added to the study during the second year, making a total of sixteen ERCs now the subject of this second year report. The interviews explored the Centers’ progress in moving toward self-sufficiency, particularly the emerging funding mix intended to replace NSF base support and the impact of self-sufficiency on the ERC culture attained under NSF support.

Patterns observed among seven ERCs in the first two cohorts of ERCs (established in 1985 and 1986) were influenced by one anomalous factor. Unlike subsequent cohorts, these ERCs had all devoted considerable time and energy to the extended process of applying for a new ERC award, perceiving that the chances for success were reasonably good.¹ This had the effect of diverting energy and resources from serious attention to self-sufficiency until these ERCs had as little as two years to achieve it.

There were, in fact, marked differences observed in the seven Centers that were part of the first and second cohorts of ERCs established in 1985 and 1986 and the nine Centers that were part of the third, fourth and fifth cohorts established in 1987, 1988, and 1990. Each of the seven ERCs in the first and second cohorts is still an economically viable entity of focused research activity. However, some of the original ERCs have remained intact as centers, some have become broadened to larger units or institutes with the earlier research activities of the ERC now functioning as a center or laboratory within the broader entity, and still other have broken apart such that pieces of the original ERC remain as centers or laboratories, but not the original whole. Of these, the two ERCs that had evolved into a broader institute had most nearly met the goal of *survival as an ERC*. Still, both have remaining concerns about the increased focus on shorter term, more applied research with a concomitant decline in the more fundamental research that underlies future applications, and both, at least at the level of the umbrella institute, have largely lost the research coherence that derived from the ERC focus on strategic planning. The other five original Centers from the first two cohorts have also, to varying degrees, experienced a shift to more industrially oriented applied research and a decline in the longer term core research often supported through the NSF/ERC Program funds. In addition, downsizing was visible to at least some extent in these Centers, and in two the amount of downsizing was dramatic. These Centers tended to have fewer faculty and students involved, research teams were often splintering, and faculty were writing considerably more individual grant proposals. Most had experienced some decline in the number of Center administrative staff, and the continuing support of the core, soft-money staff was a concern at almost all of these ERCs.

Although some of the nine Centers in the third, fourth, and fifth cohorts had begun to experience declines in ERC program support at the time of the second year interviews, none had as yet evidenced any strong shifts away from the ERC culture. Most were currently maintaining a strong history of interdisciplinary interaction, industry involvement, undergraduate and graduate student participation in team-based research, and active education and outreach programs. Nevertheless, there were considerable differences among Centers in both how they were approaching the transition and the degree of confidence they had in their ability to survive, especially with key ERC characteristics intact. One had already disintegrated into sub-component units, another seemed prepared rather quietly to fade away, and an additional three seemed to be fighting hard to weather what they perceive as a few very rough years ahead. Most reported concerns that they would be affected by the loss of NSF support in ways that mirrored the changes experienced by ERCs in the first and second cohorts.

¹ Three of the four Centers in the first cohort had successfully competed for new ERC awards and two of the Centers in the second cohort were successful through all stages of the new competition up to the final site visit, at which point their proposals were declined.

The transition planning process has varied from one Center to another. Some Centers adopted a very closed process, with only key Center personnel/faculty intimately involved. Others employed a widely inclusive process, with nearly all faculty and sometimes even students involved in the discussions. University administrators, from provosts to deans to department chairs, have had varied levels of involvement in discussions and decisions regarding the transition: some were deeply involved and supportive, while others were simply kept in the information loop. Some remained almost totally excluded. Those Centers experiencing more active involvement of the university administration generally seemed to be faring better than those with less involvement.

Overall transition strategies differed substantially from Center to Center, and even within a single Center, these strategies were sometimes in flux. However, the most commonly seen components in specific transition plans were the following:

- formation of a broader institute of which the Center would become one component;
- competition for a new ERC in a different but related area;
- application for an Industry/University Cooperative Research Center (I/UCRC) award;
- competition for a long-term, multi-million dollar award from another Federal agency or industry consortium;
- increased industry membership fees or broader membership;
- increased income from patents and spin-offs;
- increased user fees for laboratories and facilities;
- increased return of indirect cost recovery or direct subsidies from the university or State; and
- grants from NSF's Education Directorate or other sources to continue certain education functions.

On the whole, this second-year set of interviews with the first five cohorts of ERCs reinforces the finding from the first-year interviews that most Centers will survive financially, but on a reduced scale. Most Centers will experience the centrifugal effect of an increase in individual PI awards, with a concomitant decrease in the extent of cross-disciplinary, team-based research. Most Centers will also see an increase in the proportion of mission agency or industry support, which in turn will narrow the scope and shorten the time frame of research efforts in significant ways. In particular, part or all of the core, fundamental research focus will be lost as the research shifts to more applications-oriented, shorter-term projects. This has implications for student involvement in the research, as many of these projects may be unsuitable for dissertation research. The absence of NSF support is likely to affect the educational components of the Centers in additional ways. NSF funding was often used to support masters and undergraduate student involvement in Center research, diversity and outreach programs, as well as doctoral student support. Few Centers felt that they would be able to maintain these programs at the level they enjoyed under NSF funding.

All of this indicates that the self-sufficiency model that NSF initially assumed – sustainability *as Engineering Research Centers*, with all or nearly all of NSF's defining ERC

characteristics – is not an accurate reflection of the experience of most Centers in the first five cohorts. Nevertheless, some Centers seem far more likely to survive, and with a far greater retention of ERC-like characteristics, than do others. Those that appear to fare best in the process are those with the following features:

- strong institutional support in a culture that fosters ERC-like characteristics;
- a faculty that is motivated to continue participation, with institutional incentives that further that motivation;
- a strong commitment to and appreciation for the goals of ERC educational programs; and,
- to a lesser extent, a research program that lends itself to a continued evolution at the forefront of its discipline.

Early and thoughtful transition planning also appears to play a role, but its significance is highly dependent on the production and successful implementation of imaginative strategies.

On the other hand, the evidence seems to suggest that a preponderance of characteristics indicating strong industrial support may – at least when not combined with some of the institutional, faculty, and educational factors that seem to correlate strongly with transition success – actually work *against* a Center’s survival with ERC-like characteristics. Many Centers have expressed a concern about an increase in short-term, more applied research projects as the reliance on industrial funding increases. While industry was said to value the longer-term, more fundamental research that for the most part was supported through the NSF funding, the perception was that industry is generally unwilling to support it. In addition, industrial funds are generally non-discretionary, and usually cannot be used to support infrastructure or educational activities. Finally, to the extent that industry did and does support the more collaborative, cross-Center type activities, it has been largely through consortia membership fees that many Centers fear will decline in the absence of a continued rationale of leveraging NSF funding.

The first two years of the study documenting the transition to self sufficiency of mature ERC suggests that the model of sustainability originally envisioned by NSF is flawed; while most Centers will continue to exist as financially viable entities, few appear able to retain all or nearly all ERC-like characteristics once NSF base support comes to an end. In light of this, NSF essentially has two policy options: 1) continue to choose to invest in new fields and new universities; or 2) choose instead to provide some continued support to graduated ERCs. If NSF should choose the latter, the following alternatives, many of which were suggested by ERC-associated interviewees, have emerged from the study to date:

- Allow existing Centers to recompete with newly proposed Centers on an absolutely equal footing, without a requirement that they reinvent themselves.
- Reevaluate the eleven-year, fixed period of support: while Centers should continue to be reviewed intensely, if after eleven years they are still viable as centers of excellence, NSF should have the flexibility to continue to fund them as full ERCs representing “national assets”. Further, consider creating a separate pool of funding for the continued funding of the most successful

ERCs beyond the eleventh year so as to eliminate the competition with *new* ERCs, which is perhaps inherently unequal.

- Continue, as long as justified by review, to fund Centers that are still viable at a level sufficient to support the core research and infrastructure that are most vulnerable.
- Continue to provide to all graduated ERCs a small amount of annual funding to maintain their inputs into the ERC database and participate in annual ERC meetings.
- Provide continued support and recognition to graduated Centers to encourage them to continue to think of themselves as ERCs and benefit from an ongoing NSF “stamp of approval.”

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FIRST YEAR REPORT

Introduction

In 1997, the Science and Technology Policy Program of SRI International began a series of interviews with Engineering Research Centers (ERCs) at or nearing the eleventh year of support from the ERC Program within the National Science Foundation's Directorate for Engineering. The objective has been to study the transition to self-sufficiency for more mature ERCs, their progress in achieving that goal once NSF base support ceases, and the impact of self-sufficiency on the ERC culture attained under NSF support. The multi-year study is concerned not merely with the survival of these Centers as economically viable entities – there are literally hundreds of centers in universities today, but with their survival *distinctly as ERCs*. The question is one of which key characteristics of an ERC remain intact, to what extent do they remain intact, and, ultimately, why do they or do they not remain intact. If Centers are moving away from embodying key ERC characteristics, what are they evolving into and what motivates that evolution? Much will be made of this distinction between survival as a center and survival as an *ERC* in this first-year report and in subsequent reports under this study.

The ERC Program was designed to create long-term partnerships between universities and industry, create knowledge and technology to advance next-generation engineered systems, and prepare a new generation of engineering leaders who are more capable of engaging successfully in team-based, cross-disciplinary engineering practice. Individual ERCs provide an integrated environment for academe and industry to focus on next-generation advances in complex engineered systems important for the Nation's future. From NSF's perspective, key characteristics of an ERC might be characterized as follows:

- An engineered systems focus and strategic planning drives an ERC's research;
- An ERC's general organizing principle assumes total integration of research, education, and industry;
- ERCs are interdisciplinary: the engineered systems work has yielded an integration of disciplines;
- Undergraduate as well as graduate students participate in cross-disciplinary research teams and systems-level activities in ERCs;
- ERCs enhance curriculum and degree programs on the campus;
- ERCs have a strong level of financial commitment by companies and industry representatives;
- ERCs have university commitment to their continuation.

Twelve Centers were included in the first year of the study: two from the first cohort established in 1985², five from the second cohort established in 1986, two from the third cohort established in 1987, and three from the fourth cohort established in 1988. A list of these Centers

² Three of the four Centers from the first cohort had successfully recompeted for additional years of NSF funding, and two of those three had sufficient years of ERC funding ahead that they were not approaching the "graduation" point during the first year of this study; therefore, only two of the four Centers in the first cohort were part of the first year interviews.

is provided in Table 1. At each of these ERCs, interviews were conducted by two senior SRI staff over a two-day period with the Center Director, thrust leaders, faculty and researchers, students associated with the Center, the Industrial Liaison Officer, the Financial/Administrative Manager, and the Education Director. Also interviewed were Chairs/Heads of departments with which the ERC faculty are associated, the Dean of the School/College of Engineering, and the university's Vice President/Provost for Research. A copy of the Interview Guide is shown in Appendix A. The Centers will continue to be tracked in subsequent years, with additional Centers added to the study as they near the eleventh year of ERC Program support.

Table 1
NSF Engineering Research Centers Included in the Study

Award Year	ERC Institution	Field of Research
1985	Columbia University	Telecommunications
1986	Brigham Young University/University of Utah	Combustion Research
1986	Carnegie Mellon University	Design Engineering
1986	Lehigh University	Construction of Large Structures
1986	Ohio State University	Net-Shape Manufacturing
1986	University of Illinois	Microelectronics
1987	Duke University	Emerging Cardiovascular Technologies
1987	University of Colorado/Colorado State University	Optoelectronics
1988	North Carolina State University	Advanced Electronic Materials Processing
1988	Texas A&M University/University of Texas	Offshore Technology
1988	University of Minnesota	Interfacial Engineering
1985/1994	University of Maryland	Systems Engineering

The study itself is a descriptive effort. With the agreement of NSF, interviewees were promised “confidentiality” and requested to speak as frankly and openly as possible about their success with and concerns about the graduation process and any problems they are encountering. Individual site visit reports on each of the Centers included in the study are provided in Part II of this report as confidential internal working documents. The remainder of Part I addresses some of the issues and themes that emerged across all twelve ERCs included in the first year study.

Current Status of the ERCs

NSF's operative policy for ERC's is that by the end of the eleven-year cooperative agreement, ERCs are expected to "graduate" from the program and become self-sustaining entities, unless they choose to compete for a brand-new ERC award with a significantly different focus and are successful in that competition. NSF's stated policies regarding recompetition and self-sufficiency have evolved over the years. Appendix A summarizes these policies as stated in various annual ERC Program Announcements. Perceptions of the Centers regarding these NSF policies, and the likelihood of their securing a new ERC award, were often an important factor in how they approached transition planning, which, in turn, appears to have had a substantial effect on their current status.

There were fairly marked differences between the patterns observed in the first and second cohorts of ERCs and in the third and fourth in terms of the current status of the Centers. The first and second cohorts had already experienced a noticeable or substantial decline in the amount of funding they received from NSF and were already feeling its impact, a situation which had generally not yet affected the third or fourth cohorts. In addition, practically all of the Centers in the first and second cohorts had devoted time and energy, often considerable, to the process of obtaining a new ERC award in the belief that they had a reasonably good chance of securing ongoing ERC Program support. The expenditure of resources in this way diverted and/or delayed efforts to devote any serious attention to self-sufficiency until they sometimes had as little as two years to achieve it. The third and fourth cohorts, on the other hand, having observed that none of the second cohort received a new award and that NSF Program Announcements now more specifically stated expectations regarding self-sufficiency and the requirement for a new vision for a new ERC, assumed that successful recompetition would be very difficult and began thinking seriously about self-sufficiency somewhat earlier in the eleven-year cycle.

First and Second Cohorts

Among the seven Centers in the first and second cohorts of ERCs included in this study, for which NSF ERC funding had declined by about a third one or two years prior to the site visits, all but one were downsizing to at least some extent, and two quite dramatically. The one exception was an ERC for which a line item in the State Budget has allowed for quite a bit of stability, at least at the Institute level of which the ERC is a component. In most cases, however, these ERCs had fewer faculty involved, and fewer students. Projects and sometimes entire research thrust areas had been dropped. Faculty were writing considerably more individual grant proposals. With the exception of one ERC where a strong tradition of interdisciplinary, cross-departmental interaction has long been the case, there tended to be less interdisciplinary and cross-departmental research, and research teams were often splintering and doing their own things. In most cases, however, this was driven by the need to seek new research funds, which often did not provide the opportunity for team-based research. Faculty generally had come to appreciate and enjoy working in interdisciplinary teams and regretted the decline in opportunities for this sort of collaboration. Those Centers that had contiguous physical space or their own "building" tended to have maintained interaction more easily.

Four of the Centers in the first and second cohorts had changed or were in the process of changing to new Directors. Most had experienced some decline in the number of Center administrative staff or shifted these staff to broader “umbrella” institutes that house the ERC along with other centers and initiatives. The continuing support of the core, “soft-money” staff was a concern at almost all the Centers.

Most of the Centers reported an increase in short-term, more applied research projects, as the reliance on industry funding increased. Though many felt that industry valued the longer term, more fundamental research³ that for the most part was supported through the NSF funding, the perception was that industry is generally unwilling to support it. One Center reported actually losing some of its industry sponsors because the Center was unable to continue some of the more fundamental research efforts that represented the primary interest of these sponsors in participating. In most cases, industry involvement in the Center was about at the same level as it had been previously, although in some cases there had been considerable change in the companies comprising the Center membership, as shifts had been made in research directions thought to be more viable over the long-term.

Most of these first and second cohort Centers also reported a decrease in the amount of student involvement. The first thing to go was often the free pizza and cookies at student seminars, followed by the seminars themselves. Centers differed somewhat in the level of students they tried hardest to keep involved, depending on whether they were primarily a graduate or undergraduate oriented institution. Almost all, however, had discontinued the REU program for undergraduates from other institutions. Many also reported that they were unable to maintain their special recruitment or outreach programs to underrepresented groups. In most cases, many of the changes that had been made in engineering curricula or new courses that had been introduced were being maintained. In one case, however, these new courses had been dropped, because there were no longer faculty available to teach them or students to enroll in them.

The continued commitment of the home universities to these Centers ranged from a very high level of continued financial support for a specified number of years to help the Center achieve self-sufficiency to almost complete lack of interest in whether the Center continued to exist at all. Financial assistance being provided by the home institutions ranged from direct cash contributions, to allowing the Center to retain all or part of the indirect cost recovery associated with all or some of its research grants, to cost-sharing on new proposals put out by the Center.

Patterns observed in the first two cohorts of ERCs could be an anomaly because, unlike subsequent cohorts, they perceived that they were allowed to recompute without having substantially to reinvent themselves, and thus gave little attention to the need for self-sufficiency until they had a clear need to do so. Subsequent years of this study may shed further light on this issue.

³ This is confirmed by a recent survey of ERC industry sponsors; see Catherine P. Ailes, J. David Roessner, and Irwin Feller, “The Impact on Industry of Interaction with Engineering Research Centers”, SRI International, January 1997.

Third and Fourth Cohorts

The five ERCs in the third and fourth cohorts evidenced none of the above types of shifts away from the ERC culture as yet. Most of them appeared to be in their prime, maintaining a strong history of interdisciplinary interaction, industry involvement, undergraduate and graduate student involvement in team-based research, and strong education and outreach programs. All were thinking seriously about self-sufficiency and had a transition plan in place. Like the first and second cohorts, however, there were differences among the Centers in terms of the confidence they had that would continue to look more or less the same without the ERC block funding. Several had especially strong institutional support that increased the level of this confidence. Nevertheless, it appeared that few, if any, were likely to retain *all* characteristics of an NSF ERC, and most reflected concerns that they would be affected by the loss of NSF support in ways that mirrored those of the first and second cohorts.

General Overview of the First Four Cohorts

On the whole, this first-year set of interviews with the first four cohorts of ERCs would indicate that although most Centers will survive financially, it will be on a somewhat to moderately reduced scale. Some will be absorbed into an Institute that includes other centers and activities and in which the administrative infrastructure is primarily retained at the Institute rather than the Center level. Most Centers will see an increase in individual PI research, with a concomitant decrease in the extent of cross-disciplinary, team-based research. Most Centers will also see an increase in mission agency or industry support, which in turn will narrow and shorten the time frame of the focus of the research effort in significant ways. In particular, part or all of the core, fundamental research effort will be lost as the research shifts to more applications-oriented, shorter-term projects. This has implications for student involvement in the research, as many of these projects may be unsuitable for dissertation research. The absence of NSF support is likely to affect the educational components of the Centers in additional ways. The NSF funding was often used to support undergraduate involvement in the research, diversity and outreach programs, as well as graduate student support. Few Centers felt that they would be able to maintain these programs at the level they were able to with the NSF/ERC funding. All of this would indicate that the self-sufficiency model – sustainability *as Engineering Research Centers*, with all or nearly all of the ERC defining characteristics – is flawed.

Nevertheless, some Centers seem far more likely to survive, and with a far greater retention of ERC-like characteristics, than do others. About three-fourths of the Centers seem to have an even or better chance of survival as an entity; only about half, however, appear to be well positioned to survive with key ERC features largely intact. Some of the possible underlying variables for these differences in likely potential success are shown in Table 2 as working hypotheses only. As the Centers move further along in the transition process, these hypotheses will be explored in greater detail.

Table 2
Possible Underlying Variables in Likelihood of Transition Success

- Infrastructure
 Contiguous space
 Expensive facilities/equipment that need to be maintained in any case
 Low Center core administrative costs/or cost sharing of this with other units

- Transition Planning
 Early self-sufficiency planning
 Unaffected by perceived changes in NSF recompetition policies
 Intensity/complexity of the transition planning process
 Close institutional involvement in the transition planning process

- Center Management
 Recent change in Center Director for the positive
 Inclusive management style of Center Director
 Comfortable, open relationship of Center Director with associated Department Heads

- Faculty Involvement
 Incentives in place for faculty to remain involved with the Center
 Feeling of “ownership” of Center among associated faculty

- Institutional Factors
 Center’s reporting line in the university provides some protection
 Center is highly visible and prized within the larger university
 Center is assured of on-going university/State financial support
 Center is assured of on-going supportive attitude from university administration
 Center is consistent with larger university “culture” and objectives
 University policies facilitate Center-based research efforts:
 - Indirect Cost Recovery (ICR) return
 - Release time for research
 - Promotion and tenure criteria supportive of interdisciplinary research
 Smaller size of the university gives Center more prominence
 Lower stature of the university pre-ERC gives the Center more prominence

- Nature of the Research Area
 Research area is still “hot” and evolving
 Research area lends itself to expanded focus with broader faculty involvement and new industry participation
 Research progress to date gives strong prospects for income from royalties and/or spin-offs

Table 2
Possible Underlying Variables in Likelihood of Transition Success
(continued)

- *Character of Industrial Participation*

Downsizing of corporate R&D programs makes companies more reliant on university-based research

Industry participants closely involved in transition planning and strategy

Industry has few available alternatives for the Center's research

Industry is dependent on Center-educated graduates

Center has developed strong industry interactions, penetrating depth and breadth of member firms

Member companies do not object to increases in Center membership fees

- *Educational Programs*

Alternative NSF or other Federal funding sources available to maintain Center educational programs

Educational programs sufficiently valued within the university that they will be maintained

Industry participants willing to pick up some of the costs associated with student training

Faculty interest and perceived value of students' Center involvement sufficiently high to keep their students involved in Center programs regardless of source of funding

Key Issues and Concerns

The transition away from ERC Program support has ramifications broader than the decrease in available funding and the consequent downsizing that virtually all ERCs are facing without this baseline support.

First of all, the nature of the ERC support compared with funding from other sources means that the effects of its loss will be uneven across Center activities and functions. The ERCs' use of NSF funding has generally been fairly discretionary, with Centers generally using it to support the more fundamental, higher-risk, longer-term research seen as the basis of applications fairly well into the future; support for graduate and undergraduate participation in Center research teams; and costs associated with Center infrastructure, both in terms of technicians/maintenance of equipment and facilities and administrative personnel. Almost all Centers reported that while they would probably be able to find support for students by other means, albeit for fewer students, it was the core, fundamental research and the infrastructure that were most at risk, because few alternative funding sources provide such support. In the case of fundamental research, individual PI awards are, of course, available, but relatively few funding programs cover the type of cross-disciplinary research typical of ERCs. While admittedly easier to get funding for such interdisciplinary research now than even five years previously, the amount of effort needed to get a \$50,000 or \$70,000 NSF grant was thought to be almost comparable to writing a major journal publication. Furthermore, it was thought that the sum of such individual awards, even if interdisciplinary, would not equal the whole that was the ERC's fundamental research effort; it was considered difficult to go after individual awards in a coordinated, integrated fashion along the lines that the strategic planning process made inherent in the ERC approach. The perception was that while industry values the fundamental research, it will not generally support it. The infrastructure was seen as particularly at risk, in that few government grants or contracts provide this type of support, and certainly not at the level enabled by the ERC Program funds. While faculty were thought likely to be able to continue to support some students, the ability to maintain the cross-disciplinary, team-based efforts was questioned.

Second, there is another type of loss associated with the absence of ERC Program funding: prestige. NSF ERC status was considered a major contributor to the prestige and standing of the university and/or academic departments involved. Without it, there is not only the loss of much of the rationale for industry support through leveraging of NSF funding, but also the status in the eyes of other potential new sponsors, including the State governments. The NSF label reportedly makes a difference. Industry was said to be puzzled, at best, about the Centers' loss of NSF funding: if the research is of high quality and producing valuable results, then why is NSF abandoning it? This makes it even harder for industry representatives to justify their expenditure, however small, on continued membership in the ERC. Although NSF has reportedly offered that "graduated" Centers may continue to bear the name "Engineering Research Center", most interviewees felt that this would not carry the same weight without at least some continued NSF ERC funding.

Transition Planning, Strategies, and Implementation

As noted previously, most ERCs in the first and second cohorts originally recompleted for NSF/ERC funding beyond the eleventh year; transition planning at these Centers, therefore, did not begin until they learned that they had been eliminated from the recompetition process. For some Centers, this was at the pre-proposal stage, others made it to the full proposal stage, and still others to the NSF site visit following a favorable review of the full proposal. Centers in the third and fourth cohorts generally began planning once they began to see that Centers in the second cohort were not being refunded.

The planning process has differed considerably from one Center to another. In some Centers, this has been a very closed process, with only key Center personnel and faculty intimately involved. In others, it has been a very inclusive process, with nearly all faculty and sometimes even students involved in the discussions. In some cases, university administrators, from provosts to deans to department chairs, have also been very involved in discussions and decisions regarding the transition, while in others they have merely been kept informed, and in still others, almost totally non-involved. Those Centers with more active involvement of the university administration in general seem to be faring better than those with less involvement.

Although transition strategies as a coherent whole differed substantially from Center to Center, there were a number of common elements to the strategies being pursued by different ERCs. These included formation of a broader institute of which the Center would become one component; competition for a new ERC in a different but related area; application for an Industry/University Cooperative Research Center (I/UCRC); competition for a long-term, multi-million dollar award from another Federal agency or industry consortium; increased industry membership fees or broader membership; increased income from patents and spin-offs; increased user fees for laboratories and facilities; increased return of indirect cost recovery or direct subsidies from the university or State; and grants from NSF's Education Directorate or other sources to continue certain education functions.

Formation of an Institute

A number of Centers were considering the formation of an institute in which the Center would become one component. Among the advantages to this concept was the ability to centralize the infrastructure at the institute level, thus spreading the costs associated with it across a broader base. This was seen as having the additional advantage of preserving some of the Center's learned skills in running center-like activities and making use of them in new efforts. In addition, at a number of universities, institutes report to the Vice President/Provost for Research, whereas Centers report to the Dean; conversion to an institute therefore removed one layer of administrative hierarchy that had a call on a share of the Center's ICR and would thus result in increased overhead return to the Center. The concept often also included a specific charge that the institute represent multi-disciplinary, cross-departmental activities, and it was felt that this charge would help to maintain the ERC-like, team-based culture. One difficulty sometimes foreseen in the formation of an institute was that institutes generally have major block funding and/or an endowment that gets them started and provides the momentum for additional

support, and some Centers were struggling with how to accomplish this. In terms of survival of the ERC *per se*, the formation of an institute does not necessarily insure this, and Centers absorbed into an institute may look quite different from what they did as an NSF-supported ERC.

Applying for a New ERC

The transition strategy at a number of Centers included plans to apply for a new ERC in a different but somewhat related area. The difficulty here was that to meet the current NSF guidelines for re-competing, the Center has to look sufficiently different that many of the current research thrusts and faculty supported under the Center would not receive continued support even if the Center were to compete successfully. The NSF requirement was seen as a bit of a Catch 22: if a Center is strong in its current research area, why should it have to reinvent itself significantly to be allowed to compete for ERC funding? A further complication was that in a number of cases industrial sponsors had told the Centers loud and clearly that they did not want to see any changes in the Center's current research directions. The advantage of the strategy was that a new ERC would pick up much of the infrastructure, including maintenance of equipment/facilities or administrative support or both. For some Centers, the state of the art made it a natural to begin developing a substantially new, but somewhat related area; in these cases, the strategy of applying for a new ERC also offered the advantage that it would provide funding for the core, fundamental research that was considered to be the wave of the future in any event. In a number of cases, however, this strategy was being pursued more by the university administration with only half-hearted, if that, endorsement by faculty associated with the Center, as they saw little direct personal benefit to an ERC in a new, even if somewhat related, area.

Applying for an I/UCRC

Several Centers were considering applying for an NSF Industry/University Cooperative Research Center (I/UCRC) award as part of their transition strategies. It was thought that these grants would provide a framework for securing the I/UCRC Program requirement of \$300,000 unrestricted funds from new companies, which could be used to support the more fundamental work; that the \$50,000 matching funds from NSF would be useful in supporting at least some of the Center's infrastructure; and that the supplemental NSF funds for up to \$100,000 could be used to maintain some of the Center's educational programs. The dilemma here centered around the appropriateness of applying for these awards: it was thought that many current I/UCRCs are trying to position themselves to become an ERC, and ERCs looking for bridge money could inundate these programs. A number of individuals also wondered whether the associated administrative hassles were worth the effort.

Multimillion Dollar Awards from Other Federal and Industry Consortium Sources

For several Centers, the key to, and often the only hope for, sustainability post-ERC Program support was seen as obtaining a major award from a mission agency or industry

consortium. In most cases, such awards would allow these Centers to continue a good portion of their current research, although much of the more fundamental core research would remain vulnerable. Such awards would also support at least some of the Center's infrastructure, and in some cases would support some of the educational functions, as well. The downside of this strategy was considered a diversion of resources and attention to more applications-oriented problems, and a loss of at least some of the broad cohesion that currently characterized the Center's research effort as a whole. In at least one case, such funding was seen as having a major impact on both the focus and the structure of the Center.

Increased Industrial Membership Fees and Increased Membership

Part of the transition strategy for at least some Centers included an increase in their industrial membership fees, which generally were unrestricted funds that could be used to support students as well as some of the core research. Some Centers had little concern about raising these fees substantially, yet still being able to retain existing members as well as attract new ones. The more usual case, however, was great concern that increasing these fees more than a very modest amount would result in fewer members and quickly hit a point of diminishing returns. Many Centers felt that they were unable to increase these fees at all without losing members. A frequently heard comment was that without the ability to leverage the NSF funds, industry had little incentive to continue membership in any event.

Increased Income from Patents and Spin-offs

A few Centers are counting on increased income from patents and spin-off companies as one component of their plan for self-sufficiency. For this strategy to have any success, however, a Center has to have reached a level by eleven years at which it has licensed technologies or generated spin-offs that are about to generate substantial royalty income; for most Centers, this did not appear to have been the case, nor is it likely. In some cases, Centers had served as a wake-up call on intellectual property rights (IPR) and prompted vigorous university technology transfer offices. However, industry had criticized some Centers for poor IPR strategies, such as exclusive licensing when multiple would have been more effective or for pursuing a "jackpot" mentality.

Increased User Fees

Centers that are equipment/facility intensive are finding it necessary to increase user fees for these facilities just to maintain them; however, in few cases will this provide any additional revenue to help offset the absence of ERC Program funds. In most of these Centers, some of the NSF funding was used to support technicians and/or maintenance for these facilities so that they would be accessible to faculty and students, often whether directly associated with the ERC or not. It is feared that establishing or increasing user fees, as well as encouraging more outside use to earn those fees, may have an adverse impact on education by making it more difficult for students and their faculty advisors to make use of these facilities.

Institutional and/or State Support

One Center has obtained a sizeable line-item in the State budget that will ensure State funding for the indefinite future. None of the other ERCs has been quite so fortunate. Nevertheless, part of the transition strategy for a number of Centers included plans to lobby the State legislature and Congress to obtain block funding for at least some period of time. One perceived difficulty with this approach, at least at this stage in the mature ERCs' life cycle, is that removal of NSF support will signal the States that national interest in the field is declining, and hence there is no point in the State continuing to support it. A number of Centers were also seeking continued financial support from the university, either in the form of direct contributions, return of ICR, or matching funds for new research awards (usually for Federal research grants and contracts, but in one case, for new industry funding). Many of the more supportive institutions were making real efforts to provide such funding for at least some limited period. Other institutions, however, appeared either unable or unwilling to provide such financial support.

Grants from NSF's Education Directorate and Other Education Programs

Some Centers hope to use grants from NSF's Education Directorate and other sources to maintain some of their educational programs. Many of the universities, however, already have such grants in departments not related to the ERC, and for the ERC itself to obtain such grants would involve persuading the Education Directorate to add funds where it was already investing. Some Centers were trying to make creative use of individual PIs' access to REU funds in order to continue their programs for undergraduates in at least some form. Most Centers, however, either already had or intended to discontinue their REUs.

Perceptions of NSF's Role in the Transition Process

There was nearly universal frustration among this entire group of ERCs about what they considered mixed messages regarding recompeting. Those Centers in the second cohort were particularly dismayed, and often felt angry and betrayed, at what they correctly or incorrectly perceived as a change in NSF policy midstream through the competition process.⁴ Most of these second-cohort Centers indicated that reported that they felt that they *had* to write a proposal, which consumed a lot of resources that could otherwise have been spent on planning for the transition process. The further along the Centers had gotten in the recompetition process, the greater the unhappiness with NSF. Centers felt that, at the very least, NSF should provide clear guidelines on this, and stick with them; the uncertainty they felt with the process was considered very troubling.

Some interviewees felt that NSF never should have allowed Centers to recompetete; eleven years of support is sufficient, and it is time to allow the funding to shift to new awardees. Others felt that there was no reason that existing Centers should not be allowed to recompetete with newly proposed centers on an absolutely equal footing, without a requirement that they reinvent themselves. NSF was thought to have a dilemma on this: if it wants to continue to fund the best interdisciplinary research, it should in many cases continue to fund highly successful Centers already in existence; if it wants to change the culture in universities, it should probably fund only new centers. However, whether or not ERCs can develop a sustained change in the culture in a significant portion of universities remains an open question.

Apart from the question of recompetition, the eleven-year timing was often considered arbitrary: some Centers probably reach maturity and may decline within a shorter period, while others are still at the state of the art at eleven years. It was thought that the Centers should be reviewed intensely, but if they are still viable as centers of excellence, NSF should have the flexibility to continue to fund them as full ERCs.

Many thought that NSF had yet another option: continue, as long as justified by review, to fund Centers that are still viable at a level sufficient to support the core research and infrastructure that are most vulnerable with the termination of ERC funding – perhaps \$300,000 to \$500,000 per year, depending on how facility-intensive the Center is.⁵ This was thought to have the additional advantage of helping those Centers maintain and attract support from other sources: NSF funding, however minimal, was considered important in terms of leveraging other sources of funding.

⁴ While the NSF policies on recompetition evolved to some extent cohort by cohort, NSF is adamant that they were consistently administered *within* individual cohorts; the perception of a change mid-stream in the competition process may in part be due to the timing of the publication of new ERC Program Announcements for the competition the following year.

⁵ This was proposed by the ERC Program staff at the start of planning for the Class of 1985 but rejected at higher levels within NSF.

Attachment A: First Year Report

The Evolution of NSF Policies on ERC Recompetition and Self-sufficiency

As stated in the report, NSF's operative policy for ERC's is that by the end of the eleven-year cooperative agreement, ERCs are expected to "graduate" from the program and become self-sustaining entities, unless they choose to compete for a brand-new ERC award with a significantly different focus and are successful in that competition.

NSF's stated policies regarding recompetition and self-sufficiency have evolved over the years. The 1993 ERC Program Announcement stated that "Existing ERCs in the final two years of their eleven-year life cycle [the first cohort of ERCs established in 1985] are eligible to recompete for a new ERC award and may submit a proposal in this competition. These centers may propose to continue their ongoing program, or may modify their approaches for the future to address new issues that have become important in recent years." The 1994 Announcement stated that "Existing ERCs in the final two years of their initial eleven-year life span [the second ERC cohort established in 1986] are eligible to recompete for a new award and may submit a proposal in this competition. These centers will have to demonstrate both high-quality performance and a fresh, challenging vision for the future. They may propose to enhance significantly their ongoing programs, focusing on continuing work to be done, building on the past, and modifying their approaches for the future to address new issues that have become important in recent years. They also may propose a significantly different activity." The next Announcement, issued in 1996, stated that "Former ERCs, as well as ongoing ERCs at the end of their term of NSF support, and other centers are eligible to submit proposals to establish new ERCs. Proposals with teams derived from these centers will be subjected to the same review process, under the same review criteria, as are teams who have no prior center-level experience. Thus, there is neither a negative nor a positive bias toward such teams in the proposal review and award decision processes." It went on to state that "ERC funding through this announcement will not be used to replace funding by NSF or other agencies to fulfill the past goals of an ERC...."

NSF's oversight policies have at least implicitly promoted ERC self-sufficiency since the early 1990s, with funding phased down in Years 10 and 11 to encourage this. The 1993 Program Announcement made no specific mention of self-sufficiency. It did, however, state that "The eleven-year limit on an ERC's life cycle was introduced in the third year of the ERC Program. In order for an ERC to receive funding from NSF beyond this eleven-year limit, it must recompete with new proposers in an announced competition. During the award selection process, an appropriate assessment will be made of the relative value of continuing an existing investment to that of starting a completely new ERC." The following year, reference was made to "ERCs and self-sustainable academic change" and the expectation that ERCs "will have a long-term sustainable impact on the research and educational cultures in academe....While it is recognized that different centers will require different time frames to achieve this state depending upon the chosen technology, academic attitudes and infrastructures, institutional policies, etc., it is expected that the home institution(s) of the ERC will assure that changes are facilitated and endure after NSF support ends." By the 1996 Announcement, long-term self-sufficiency was defined more specifically: "NSF expects ERCs to become self-sustaining and to maintain the ERC culture beyond the end of their term of NSF support. By that time, they will

have developed an effective and productive collaboration with industrial and other partnerships. They should be prepared to continue that productive relationship with university, industrial, and other support when NSF funding ceases.”

SECOND YEAR REPORT

Introduction

This report on the second year of an ongoing study of the transition to self-sufficiency of ERCs nearing or beyond the eleventh year of support from the ERC Program provides an updated summary of the current status and transition paths of these Centers. As such, it is intended to be read in conjunction with the first year report, as an addendum.

Twelve Centers from the first through fourth cohorts of ERCs, established between 1985 and 1988, were included in the on-site interviews conducted in the first year of the study. As part of the second year of the study, interviews were conducted with representatives of these twelve Centers, either by telephone or in-person as part of a somewhat related study in process by SRI on the institutional impacts of ERC's on the universities in which they are based. Four additional ERCs were added to the study during its second year: three from the fifth cohort established in 1990, and one from the first 1985 cohort that had successfully recompeted for an additional three years of ERC Program support.⁶ Interviews were conducted on site at all four of these Centers. A list of all ERCs included in the second year of the study is shown in Table 3. These sixteen Centers will continue to be tracked in subsequent years.

Table 3
NSF Engineering Research Centers Included in the Study

Award Year	ERC Institution	Field of Research
1985	Columbia University	Telecommunications
1986	Brigham Young University/University of Utah	Combustion Research
1986	Carnegie Mellon University	Design Engineering
1986	Lehigh University	Construction of Large Structures
1986	Ohio State University	Net-Shape Manufacturing
1986	University of Illinois	Microelectronics
1987	Duke University	Emerging Cardiovascular Technologies
1987	University of Colorado/Colorado State University	Optoelectronics
1988	North Carolina State University	Advanced Electronic Materials Processing
1988	Texas A&M University/University of Texas	Offshore Technology
1988	University of Minnesota	Interfacial Engineering
1990	Carnegie Mellon University	Data Storage Systems
1990	Mississippi State University	Computational Field Simulation
1990	Montana State University	Biofilm Engineering
1985/1994	University of Maryland	Systems Engineering
1985/1994	Purdue University	Intelligent Manufacturing Systems/Collaborative Manufacturing Systems

⁶ One additional Center from the first cohort that had successfully competed for an additional eleven years has sufficient years of ERC funding ahead that it is not yet approaching the transition point and therefore has not been included in this study.

Current Status of the ERCs

As noted in the first year report, there were fairly marked differences between the patterns observed in the first and second cohorts of ERCs and those in the third and fourth. This remained true in the second year of the study. The four ERCs that were added in the second year of the study generally fit the patterns observed in the third and fourth cohorts. Therefore, the description of the current status of the ERCs that follows separates the first and second cohorts from the third through fifth, with one Center from the first cohort considered among the third through fifth which it more closely resembled at this point in time, as it was only now experiencing the decline in ERC Program funds.

First and Second Cohorts

ERC Program funds had now expired for all of the seven Centers in the first and second cohorts of ERCs included in this study. The first year report noted that this transition study is concerned not just with the survival of ERCs as economically viable entities – there are literally hundreds of centers in universities today – but with their survival *distinctly as ERCs*. The second year of the study has made it clear that survival as an economically viable entity can take many forms and that what is meant by “survival”, as a baseline, needs to be defined more clearly. Each of the seven ERCs in the first and second cohorts are still economically viable entities of focused research activity. However, some of the original ERCs have remained intact as centers, some have become elevated to larger units or institutes with the earlier research activities of the ERC now functioning as a center or laboratory within the broader entity, and still others have broken apart such that pieces of the original ERC remain as centers or laboratories, but not the original whole. In fact, it seems quite likely that, however much an ERC moves away from survival with the NSF defined characteristics intact, *something* is likely to survive as a focus of research activity if even a handful of faculty continue to conduct research with industry involvement in some sort of laboratory or other structure. The unit of analysis needs to be identified. Each of the “entities”, whether Institute, center, laboratory or thrust, differs in the degree to which it has retained ERC-like characteristics that make the remaining entity more than merely an economically viable focus of research activity. The relationship between the unit of analysis and the remaining level of ERC features is complex.

Of the first and second cohorts, the two ERCs that had evolved into a broader Institute, with the former ERC research now conducted through component labs or centers, had most nearly met the goal of *survival as an ERC*: the basic infrastructure and administrative staff from the ERC are now functioning at the broader Institute level, the research conducted in the Institute remains interdisciplinary in nature, industry involvement is still sought and encouraged throughout the laboratories or centers that comprise the Institute, undergraduate and graduate students are involved in interdisciplinary and team-based research, and many, if not all, of the educational curriculum and outreach functions formerly associated with the ERC are now among the central functions of the broader Institute. The Institutes themselves, through a combination of State, university, and outside support, are in a fairly strong and relatively stable financial situation. Still, both are struggling with the question of the precise identity of the broader Institute, both have remaining concerns about the increased focus on shorter term, more applied

research with a concomitant decline in the more fundamental research that underlies future applications, and both, at least at the level of the umbrella Institute, have largely lost the research coherence that derived from the ERC focus on strategic planning. Such strategic planning and the integration of research, education and industrial involvement *may* be present in one or more of the component units of the Institute, but this again raises the question of what is the unit of analysis – the umbrella, or the component pieces.

The four original ERCs that have remained relatively intact as Centers (although one is now labeled a laboratory and is held together largely by the existence of a building having a "clean room"), as well as the two thrust areas that remain of one ERC that is now no longer formally a Center, have all to varying degrees also experienced a shift to more industrially oriented applied research and a decline in the longer term core research often supported through the NSF/ERC Program funds. While some of these Centers/research thrusts appear to have maintained more of that coherence in their research focus formerly brought about by the ERC strategic planning process, two of these have essentially lost sight of the strong educational focus associated with ERCs. In addition, these last two Centers have an appearance of surviving largely "hand – to – mouth", with a great deal of uncertainty about their viability over the longer term.

Those Centers among the first and second cohorts that have retained the most ERC-like features at the present time have experienced extremely high institutional support and involvement compared with the others in these cohorts. This institutional support is certainly a key, if not *the* key, to their current status. State government support has been instrumental in the case of two of these, but such support has also been important in the continued survival of a Center that lacks many of the ERC-like characteristics but in which strong institutional support has also been lacking, so therefore cannot be said to represent one of the key factors in survival *qua* ERC. Those Centers that have maintained a relatively constant involvement by industry, but without much of the institutional involvement or support that characterizes others from these cohorts, no longer look much like an ERC. Without the leveraging and symbolism of ERC Program funds, the industrial support has often reverted to project specific work rather than the pooling of resources for more discretionary research. These Centers therefore tend to lack much of a focus on students, systems level research, team-based research, longer-term fundamental research, and often even the interdisciplinarity typically associated with ERCs.

The ERCs in these two cohorts, as noted in the report on the first year of this study, had generally devoted considerable time, energy, and resources to the process of obtaining a new ERC award in the belief that they had a reasonably good chance of success. This effort delayed any serious attention to self-sufficiency until they sometimes had as little as two years to achieve it. With the exception of one ERC for which a line item in the State Budget achieved early on in the Center's existence allowed for quite a bit of stability throughout the transition, at least at the Institute level of which the Center is a part, most of the Centers in these first two cohorts have experienced a good deal of turmoil in the last few years. By the time of the second year interviews in the transition study, much of this uncertainty had settled down and the surviving entities, although varying considerably from one to another in precisely what remained and how it was structured, seemed generally on a relatively steady path in terms of what they are likely to look like over the next few years. Only one of the seven had distinctly lost its structure as a

formal "center", and even it had two surviving thrusts that embody some ERC-like characteristics and appear to be relatively stable.

Third, Fourth, and Fifth Cohorts

Although some of the nine Centers in these cohorts (including the one from the first cohort that had obtained three additional years of ERC Program funds) had begun to experience declines in ERC Program support at the time of the second year interviews, none had as yet evidenced any strong shifts away from the ERC culture. One had very recently been disaggregated into several component parts, one representing the industrial interaction, another the education, and another most of the research associated with a fairly expensive facility, but this was largely the result of an award for a new NSF Materials Research Science and Engineering Center (MRSEC) which had taken over part of the thrust areas of the ERC; despite the disaggregation, ERC-like characteristics remained visible in the separate units and in the university's efforts to maintain them. Most Centers in these cohorts were currently maintaining a strong tradition of interdisciplinary interaction, industry involvement, undergraduate and graduate student participation in team-based research, and active education and outreach programs. Nevertheless, there were considerable differences among Centers in both how they were approaching the transition and the degree of confidence they had in their ability to survive. Apart from the Center that had recently been disaggregated, only one of the remaining eight seemed prepared rather quietly to fade away, although three others seemed to be fighting hard to weather what they perceive as a few rough years ahead. As with the first two cohorts, one of the key factors that appeared to correlate strongly with the continued viability of these Centers *qua* ERCs was strong support, whether financially or attitudinally, from the institutions within which they are based. Even so, as with the first two cohorts, it appears that few, if any, are likely to survive with *all* of the characteristics of an NSF ERC, and many continue to reflect concerns that they will be affected by the loss of ERC Program support in ways that mirror those of the first and second cohorts.

General Overview of the First Five Cohorts

The second year set of interviews with the first five cohorts of ERCs, while presenting a somewhat more positive outlook, by and large support the findings of the first year of the study. These were stated as follows:

On the whole, this first-year set of interviews with the first four cohorts of ERCs would indicate that although most Centers will survive financially, it will be on a somewhat to moderately reduced scale. Some will be absorbed into an Institute that includes other centers and activities and in which the administrative infrastructure is primarily retained at the Institute rather than the Center level. Most Centers will see an increase in individual PI research, with a concomitant decrease in the extent of cross-disciplinary, team-based research. Most Centers will also see an increase in mission agency or industry support, which in turn will narrow and shorten the time-frame of the focus of the research effort in significant

ways. In particular, part or all of the core, fundamental research effort will be lost as the research shifts to more applications-oriented, shorter-term projects. This has implications for student involvement in the research, as many of these projects may be unsuitable for dissertation research. The absence of NSF support is likely to affect the educational components of the Centers in additional ways. The NSF funding was often used to support undergraduate involvement in the research, diversity and outreach programs, as well as graduate student support. Few Centers felt that they would be able to maintain these programs at the level they were able to with the NSF/ERC funding. (p. 5)

The first year graduation paths report went on to note that some Centers seem far more likely to survive, and with a far greater retention of ERC-like characteristics, than do others, and hypothesized some possible underlying variables that may account for these differences in potential success. The possible underlying variables in the likelihood of transition success hypothesized in the first year report, and how these variables seem, at this stage of the study, to correlate with a Center's current outlook for self-sufficiency *qua* ERC over more than the very immediate future is provided in Table 4. It is worth emphasizing that these measures of likelihood of transition success are qualitative judgement based on impressions and observations from at most two points in time during a Center's move toward self-sufficiency, and the usual caveats associated with such judgement calls must apply.

By far the strongest positive correlation between the various hypothesized variables and the likelihood of a Center's successful transition to self-sufficiency appears to be with institutional factors: an ongoing supportive attitude from the university administration, high visibility and appreciation of the ERC within the larger university, university policies (such as promotion and tenure criteria and indirect cost recovery) that facilitate center-based research, and a reporting line in the institution that provides some protection. Factors related to faculty involvement also correlate highly with a Center's likelihood of survival with key ERC characteristics: incentives are in place for faculty to remain involved with the Center, there is a feeling of "ownership" of the Center among associated faculty. Another set of factors that seems to correlate with sustainability of ERC-like characteristics is the ability to maintain educational programs: faculty interest in and perceived value of the Center's educational components is sufficiently high that they will keep their student involved in any case, or educational programs are sufficiently valued within the institution that they will be maintained.

Factors associated with the research area in which the Center is engaged, as well as those related to transition planning, appear to have some correlation with a Center's likelihood of transition success, although considerably less strong than the factors noted above. For example, transition planning factors such as the intensity/complexity of the process, early initiation of the process, and close institutional involvement in the process all appear at least somewhat to enhance a Center's likelihood of transition success. A research area that lends itself to an expanded focus, broader faculty involvement, or new industrial participation seems to correlate somewhat with transition success, as does a research area that is still "hot" and evolving.

Table 4
Possible Underlying Variables Correlated with
Likelihood of Transition Success with ERC Characteristics Intact

Factors Strongly Correlated with ERCs Most Likely to Succeed

- Center is assured of on-going supportive attitude from university administration
- Center is highly visible and prized within the larger university
- Incentives in place for faculty to remain involved with the Center
- Close institutional involvement in the transition planning process
- Feeling of “ownership” of Center among associated faculty
- Faculty interest and perceived value of students’ Center involvement sufficiently high to keep their students involved in Center programs regardless of source of funding
- University policies facilitate Center-based research efforts
- Center’s reporting line in the university provides some protection
- Educational programs sufficiently valued within the Institution that they will be maintained
- Research lends itself to expanded focus/broader faculty involvement/new industry participants

Factors Somewhat Correlated with ERCs Most Likely to Succeed

- Intensity/complexity of the transition planning process
- Center is consistent with larger university “culture” and objectives
- Research area is still “hot” and evolving
- Unaffected by perceived changes in NSF recompetition policies
- Early self-sufficiency planning
- Smaller size of the university gives Center more prominence
- Center is assured of on-going university/State financial support

Factors Evenly Distributed between ERCs Most and Least Likely to Succeed

- Comfortable, open relationship of Center Director with associated Department Heads
- Inclusive management style of Center Director
- Contiguous space
- Firms have experienced substantial benefits to date
- Center has developed strong industry interactions, penetrating depth/breadth of member firms
- Expensive facilities/equipment that need to be maintained in any case
- Industry participants willing to pick up some of the costs associated with student training
- Industry has few available alternatives for the Center’s research
- Low Center core administrative costs/or cost sharing of this with other units

Factors Correlated with Too Few ERCs to Judge at Present

- Recent change in Center director for the positive
- Alternative NSF/other Federal funding available to maintain Center education programs
- Industry participants closely involved in transition planning and strategy
- Member companies do not object to increases in Center membership fees
- Research progress to date gives strong prospects for income from royalties and/or spin-offs
- Industry is dependent on Center-educated graduates
- Downsizing of corporate R&D makes companies more reliant on university-based research

Some of the hypothesized variables appear to have little if any correlation with a Center's likelihood of transition success. Many of these have to do with the nature of the Center's industrial participation: the Center has developed strong industry interactions, penetrating depth and breadth of member firms; industry has few available alternatives for the Center's research; industry is willing to pick up some of the costs associated with student training, or industry has few available alternatives to the Center's research. In fact, observations by SRI staff would lead us to suspect that a preponderance of industrial support factors – at least when not combined with some of the institutional, faculty, and educational factors that appear to strongly correlated with transition success – may actually tend to work *against* a Center's survival with ERC characteristics. In some ways, this is not surprising. As noted in the first year report on this study, many Centers feared an increase in short-term, more applied research projects, as the reliance on industrial funding increases. While industry was said to value the longer-term, more fundamental research that for the most part was supported through the NSF funding, the perception was that industry is generally unwilling to support it. In addition, industrial funds are generally non-discretionary, and usually cannot be used to support infrastructure or educational activities (although there are a few Centers in which such funds are distinctly targeted for such support). Finally, to the extent that industry did and does support the more collaborative, cross-Center type activities, it has been largely through consortia membership fees that many Centers feared would decline with the absence of a continued rationale of leveraging NSF funding.

It is generally too early to tell whether university funds, if substituted for NSF core support for fundamental research and infrastructure in post-transition ERCs, will market well to other sources of funding. Preliminary indications are that it does work as a basis for successful proposals to federal mission agencies, but does not lead to increased or restored levels of industry support. To the extent that the latter situations occur, it is at least partially due to loss of the NSF stamp of approval, an indication of state-of-the-art ideas, skills, and facilities that many firms found useful in justifying the costs of ERC membership.

Transition Planning, Strategies, and Implementation

As noted in the first year study report, while transition strategies as a coherent whole differed substantially from Center to Center, there were a number of common elements to the strategies being pursued by different ERCs. These included formation of a broader institute of which the Center would become one component; competition for a new ERC in a different but related area; application for an Industry/University Cooperative Research Center (I/UCRC); competition for a long-term, multi-million dollar award from another Federal agency or industry consortium; increased industry membership fees or broader membership; increased income from patents and spin-offs; increased user fees for laboratories and facilities; increased return of indirect cost recovery or direct subsidies from the university or State; and grants from NSF's Education Directorate or other sources to continue certain education functions.

The second year interviews revealed no additional major elements being pursued as part of the Centers' transition strategies, but show some changed perceptions of the problems associated with various strategies that had been identified. In particular, these related to the following:

Formation of an Institute: Several ERCs had already formed an Institute in which the Center had become one component, and a number of others were continuing to contemplate the formation of such an Institute. The benefits associated with this strategy were generally seen as before, but more individuals were beginning to see some potential *disadvantages* to this arrangement. In particular, research conducted under the umbrella of an Institute tends to be far more diffuse than within an ERC. In addition, the strategic planning process, which many Centers reported as something they had come to value highly both as underpinning the cross-disciplinary relationships and keeping everyone working toward the same "vision", tends to fall by the wayside in a broader Institute.

Applying for a New ERC: The transition strategy at many Centers continued to include plans to apply for a new ERC in a different but somewhat related area. The perceived costs and benefits associated with this strategy, if successful, remained largely the same, but the estimated likelihood of success of this strategy was greatly diminished at most Centers. None of the ERCs currently in the transition process has thus far been successful in competing for a new ERC in a related area, and it is difficult to predict what the effect might be on the long-term outlook for the original ERC *per se*.

Applying for an I/UCRC: In the first year interviews, several Centers mentioned applying for an I/UCRC as part of their transition strategies. In the second year follow-up interviews, this was no longer mentioned as a serious strategy. Presumably the appropriateness of applying for these awards when many current I/UCRCs are trying to position themselves to become ERCs, or perhaps the administrative burdens associated with these awards, had made the Centers begin to rethink this part of their transition strategies.

The other common elements of the various transition strategies of the sixteen Centers now included in the study remained much as before.

Perceptions of NSF's Role in the Transition Process

Much of the frustration about what were considered mixed messages from NSF regarding competing for a new ERC seems to have abated. While competing for a new ERC in a related area remains part of the transition strategy for many Centers, they seem to feel that they have a clear understanding of NSF's policy on this.

Some interviewees continued to question the eleven year period of support as arbitrary, while others felt that it was a sufficient time period for a Center to become established and the funding to shift to new awardees. The primary suggestion for how NSF could help in the transition process was to continue to fund the core research and infrastructure, as long as justified by review, at a level of \$300,000 to \$500,000 per year.

Most of the Centers that are no longer receiving ERC Program funds reported that they have maintained little, if any, ongoing communications with the program. Some reported that while they felt that their experiences with transition to self-sufficiency could be of interest and use to some of the newer Centers, they cannot justify the costs associated with attending the various ERC Program meetings and seminars to share these experiences now that they are no longer receiving program funds.

Possible Policy Options for NSF

The two year study documenting the transition to self-sufficiency of mature ERCs suggests that the model of sustainability as *Engineering Research Centers*, with all or nearly all of the ERC defining characteristics intact, is not an accurate reflection of the experience of most Centers in the first five cohorts. Those that appear to fare best in the process are those with the following features:

- strong institutional support in a culture that fosters ERC-like characteristics;
- a faculty that is motivated to continue participation, with institutional incentives that further that motivation;
- a strong commitment to and appreciation for the goals of ERC educational programs; and,
- to a lesser extent, a research program that lends itself to a continued evolution at the forefront of its discipline.

Early and thoughtful transition planning also appears to play a role, but its significance is highly dependent on the production and successful implementation of imaginative strategies.

This raises the question of what NSF can do to increase the likelihood of the successful transition of Centers to self-sufficiency with ERC characteristics largely intact once the base support from NSF comes to an end. There are two potential points of intervention. The first is in the various review stages during the life of an ERC. The second is in the years following the graduation of a Center after the eleventh year of ERC Program support.

Possible Interventions in the Sixth Year Review Process

NSF has already begun to emphasize the need for early planning for self-sufficiency by including this area as one of the factors that must be discussed in the original proposal to establish an ERC and in the criteria to be assessed by site visit teams in the sixth year renewal review. Included in the review criteria is a section on university commitment, asking reviewers to assess the administration's oversight, management, and other administrative support to the Center, as well as the strategies for promotion and tenure. In conjunction with an assessment of the current university commitment to the Center, reviewers should probably also attempt to ascertain what that commitment is likely to look like once NSF support ceases. An additional factor that might be included under this category as a predictor of long-term sustainability is the administration's interest in and commitment to the educational programs carried out by the Center.

The sixth year review criteria also include a category that relates to the faculty team. The factors to be assessed by reviewers, however, relate primarily to the quality and diversity of the faculty involved and the management capabilities of the thrust leaders. Additional factors that might be included under this category are the level of *faculty* interest in and commitment to the educational programs carried out by the ERC, as well as the motivation and incentives for faculty to remain involved with the Center.

The review criteria already ask about the nature of the research and whether the vision and goals present a compelling case for future investment by non-ERC Program sources, such as industry, other NSF programs, or mission-oriented agencies. The reviewers should also be asked where they see the research heading over the longer term, and whether the Center appears to be on the right track to insure that it stays at the cutting edge.

Options Near or After the Eleventh Year

What might NSF do to assist Centers in their sustainability after the eleventh year? Given that even the most “successful” ERCs have difficulty retaining their ERC-like characteristics after NSF support ends, the question for NSF involves a tradeoff between the costs of ensuring the survival of successful ERCs *as* ERC-like entities beyond transition, and initiating new ones. A related question is the extent to which the concept of ERCs (not just industry-university research centers) has diffused among research universities as desirable, if complex, ways of operating. The answer to this will partially influence the tradeoffs between ensuring that successful ERCs continue to exist versus creating new ones.

As noted previously, the Centers use of ERC Program funding has been fairly discretionary, with the funds generally used to support the more fundamental, higher risk, longer term research that is the basis of future applications; graduate and undergraduate participation in research teams; and Center infrastructure, including technicians/equipment maintenance and administrative personnel. Of these, the most vulnerable post-ERC Program elements were generally thought by university participants to be the following:

- the core, fundamental research – which industry and mission-oriented agencies typically will not directly support;
- the infrastructure – for which few government grants or contracts provide support and certainly not at the level enabled by the ERC Program funds; and
- the undergraduate students.

While most Centers reported that faculty would probably continue to be able to find support for graduate students, albeit fewer students, the undergraduate involvement was especially at risk.

Apart from some interventions at the sixth year review, there are several possible options for NSF in the years immediately *following* the graduation of a Center after the eleventh year of ERC Program support comes to an end to increase the likelihood of its continued survival with ERC characteristics largely intact:

- Allow existing Centers to recompete with newly proposed Centers on an absolutely equal footing, without a requirement that they reinvent themselves.
- Reevaluate the eleven-year, fixed period of support: while Centers should continue to be reviewed intensely, if after eleven years they are still viable as

centers of excellence, NSF could have the flexibility to continue to fund them as full ERCs.

- Continue, as long as justified by review, to fund Centers that are still viable at a level sufficient to support the core research and infrastructure that are most vulnerable.
- Continue to provide to all graduated ERCs a small amount of annual funding to maintain their inputs into the ERC database and participate in annual ERC meetings.
- Provide continued support and recognition to graduated Centers to encourage them to continue to think of themselves as ERCs and benefit from an ongoing NSF imprimatur.

The first option above, that of allowing mature ERC to compete on an absolutely equal footing with new ERCs, without having significantly to reinvent themselves, has the advantage over the present policy of allowing NSF to continue funding those ERCs that remain at the cutting edge of their fields, as well as show evidence of all other qualities required in the review process for new ERCs. In a real sense, such ERCs have presumably continuously “reinvented” themselves in order to remain at the forefront of the state-of-the-art in their disciplines. The disadvantage of this option, of course, is that for each such existing Center that gets funding as a “new” ERC, NSF will have the resources to fund one fewer promising proposal for an ERC in a new area, at perhaps yet another institution that has not yet had the advantage of the cultural stimulus on the campus often provided by an ERC to its home institution. In addition, should an ERC elect to compete for a new ERC, even without having significantly to reinvent itself, considerable time and resources are required for that process that could otherwise be spent preparing for self-sufficiency. There is the downside that if such Center’s compete for a new ERC and *lose*, the net effect is counter to its best interests in terms of sustainability. Finally, existing ERCs, particularly those that are at the top of heap in the quality of their current programs, would have some built in advantage compared with newly proposed ERCs in knowing exactly what NSF is looking for and being able to prepare a convincing case for reviewers; it might be difficult for NSF to specify exactly what is meant by “an absolutely equal footing” in such a way that reviewers would easily be able to reject a proposal from an existing Center, thus, in effect, giving existing ERCs a built-in advantage in the competitive process.

The second option, that of continuing to fund Centers as full ERCs as long as they are still viable as centers of excellence (that is, remove the rather arbitrary, fixed eleven-year maximum period of support), has a similar advantage to that above of maintaining those ERCs that remain at the cutting edge of their disciplines and in other respects show all of the signs of vitality and continued growth expected of Centers in their sixth year review and subsequently. The second option also removes at least one disadvantage of the first, in that presumably a renewal funding process would not have the downside of the enormous investment of time and resources required to compete for a new ERC, nor the negative impact on the timely devotion of attention to self-sufficiency, should a Center be unsuccessful in this process. The review process

for such continued funding could perhaps take place in the tenth year, extending the funding for an additional three years until another review would take place for an additional three years, and so on. If NSF were to create a separate pool of money for the continued funding of ERCs, subject to intense review, beyond the tenth/eleventh year, the competition with proposals for *new* ERCs, which is perhaps inherently unequal, would be eliminated. While this option has the disadvantage, like the first, of simply adding additional demands on already constrained resources, NSF might consider seeking “new” funds for such a purpose. It is always a political risk to seek “new” funds in that the result will be a shuffling of existing funding, no matter what the initial intent. However, in the current favorable economic conditions and with the widely held perception of the role of technology in driving the economy, it seems worth considering an effort to set aside an additional funding source devoted to preserving the most successful of those ERCs due to graduate as “national assets”.

A third option, favored by most of the Centers interviewed if neither of the first two options is considered viable, would be for NSF to continue to provide some level of core support – \$300,000 to \$500,000 annually was the range usually mentioned – for those Centers that could justify such support in an annual review. With eighteen Centers now having reached or about to reach the eleven year mark – and that number growing in the future – if only a third could justify such continued funding, NSF would need to budget on the order of \$1.8 to \$3.0 million a year for this. And that does not include the additional costs associated with continued review. Of course, many Centers would probably find it helpful to have continued base support of even \$100,000 or \$150,000 annually, which would reduce replacement funding needs accordingly – unless the reporting requirements associated with those additional funds were sufficiently burdensome to eat up much of what was being added.

A fourth option might be to continue to provide roughly \$25,000 to \$50,000 annually for Centers to maintain their inputs to the ERC database – the most important of those indicators, in any case – and to participate in annual ERC meetings. The indicators would provide a means for NSF to continue to monitor the direction the Center is taking and its continued viability, while participation in annual meetings would enable sharing of lessons learned with newer Centers or those about to confront the transition themselves. Although graduated Centers are currently invited to these meetings, many are reluctant to dip into already strained resources to support the costs associated with attendance. If offered to and exercised by *all* graduated ERCs, this option would cost on the order of \$.5 to \$1.0 million a year at the current number of graduated Centers.

One of the advantages of either the third or fourth options above is that the continued provision of funding by the ERC Program, no matter how minimal, might have the effect of making Centers find it more legitimate to continue to refer to themselves – and to *think* of themselves – as ERCs and part of the ERC “family.” While NSF has told the graduated Centers that they may continue to use the ERC title, few seem to be comfortable doing so and some actually resent the suggestion. With some continued funding, this attitude might change. It could have the effect, at least in part, of off-setting what many considered a key loss associated with the absence of ERC Program funding: prestige – especially the NSF stamp of approval. Without at least some continued ERC Program funding, many thought there was a loss not only of the rationale for industry to leverage its funding, but also of status in the eyes of other potential new funding sources. Continued support at even a nominal level might actually impact

positively on the ability of these Centers to maintain and find additional support from other sources. Perhaps more importantly, if a small amount of continued funding were to have the effect of making Centers continue to *think* of themselves as ERCs, this in turn might make them retain awareness of the unique features of an ERC and strive harder to maintain those characteristics.

The fourth option above – that of providing some continued nominal funding to all Centers to support data collection and attendance at annual meetings – is not without its potential downside in addition to added costs. Some graduated Centers bear little resemblance to what NSF means by an ERC and the number of such Centers could well increase as the time without significant ERC Program support lengthens. Having such Centers continue to refer to themselves as ERCs might dilute the impact of the prestige associated with the ERC name. In all likelihood, however, Centers that have drifted too far from the ERC model are well aware of that fact and would not be comfortable continuing to be referred to as ERCs in any event.

Finally, there may be low-cost ways of providing continued support for graduated Centers. (All of the following options require that NSF be satisfied that the graduated Centers are sustaining a level of quality characteristic of the program.) One means of making Centers continue to feel part of the ERC “family” is to do as NSF does now by including contact information on graduated ERCs on the NSF/ERC Web page. At a Center’s request, another possibility would be NSF participation in industrial member conferences and workshops that a Center convenes to show continued interest and support for the Center, even though direct ERC Program funding has now been allocated to support new initiatives.

An important role for supporting high quality graduated Centers lies in sustaining the NSF stamp of approval and sense of leveraging of NSF funding that appears to be very attractive and important to industry. A proactive stance in helping these Centers connect with new funding sources of which NSF becomes aware or initiates is one way to do this. Subject to quality assessment, NSF ERC Program Management might include references of other support as graduated or soon-to-be graduated ERCs seek funding from other sources – Federal government agencies in particular.

Center investigators also turn to other NSF programs for support. While some proposal efforts involve individual PIs, other programs now aim at supporting multi-investigator interdisciplinary projects. In either case, when ERC researchers are successful in obtaining significant new funding packages from non-ERC NSF sources, the ERC Program might participate in press releases or other announcements of the award, again emphasizing the NSF stamp of approval and that continued support of the ERC by firms represents continued leveraging of NSF funding.