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ABSTRACT

This document concerns the operation and evaluation of the National Science Foundation (NSF) Engineering Research Center (ERC) program. Included with a general letter addressing the operation of the program are several appendices which attempt to answer the questions put forth in the letter. These appendices include considerations of: (1) objectives, scope and methodology of ERC; (2) selection process used by ERC; (3) monitoring of ERCs by NSF; (4) evaluation process used by NSF; (5) reasons for participating in a program and continuing support provided; (6) engineering education and interactions of industry and universities; (7) collaboration, research results, and technology transfer of ERCs; and (8) a profile of the industry. Also included are locations of ERCs for 1985-87 and results of the General Accounting Office surveys of the NSF's ERCs and industrial participants. (ML)

United States General Accounting Office

GAO

Report to Congressional Requesters

August 1988

ENGINEERING RESEARCH CENTERS

NSF Program Management and Industry Sponsorship

GAO/RCED-88-177

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-227247

August 16, 1988

The Honorable Ernest F. Hollings, Chairman
The Honorable John C. Danforth, Ranking Member
Committee on Commerce, Science,
and Transportation
United States Senate

The Honorable Don W. Riegle, Jr., Chairman
The Honorable Larry Pressler, Ranking Member
Subcommittee on Science, Technology,
and Space
Committee on Commerce, Science,
and Transportation
United States Senate

As requested in your October 1, 1987, letter, we examined selected aspects of the National Science Foundation's (NSF) Engineering Research Center (ERC) program. You were particularly concerned about NSF's operation and evaluation of the program, including NSF's criteria for selecting the centers, its role in ERC management and research agenda, the methodology it will use to evaluate the centers, and what the evaluation might tell about the strengths and weaknesses of the ERC approach. You also asked about industry sponsors' reaction to the program, including the kinds of companies participating; the benefits to them in terms of research, competitiveness, and education of new engineers; their intentions regarding continued support; and aspects of the ERC program they would like to see strengthened or changed.

Concerning NSF's operation and management of the program, we found the following:

- Although not explicitly stated, research quality is the most important criterion in selecting a center, with its contribution to industrial competitiveness and education following in importance.
- NSF formally monitors ERC management and research agenda through yearly on-site reviews and ERC-prepared strategic plans.
- NSF uses outside peer reviewers to evaluate individual ERCs once every 3 years but believes it is too soon to evaluate the overall strengths and weaknesses of the ERC approach.

Concerning industry reaction to the program, we found the following:

- A wide range of industries participate in ERCs and most intend to continue their support.
- Participants believe that the type and quality of research is the most important reason for sponsoring ERCs. They expect to benefit over time through better personnel recruiting and improvement of current personnel but not through patentable or commercialized products.
- It is too early to determine the program's impact on engineering education because it has been in place for only a short period of time, and industry sponsors have not hired many graduates of ERC programs.
- The aspect of the ERC that participants most often mentioned as needing to be strengthened or changed was their input to and influence on the ERC's research agenda.

Background

The ERC program was established in April 1984 with the goal of developing fundamental knowledge in engineering fields that will enhance international competitiveness of U.S. industry and prepare engineers to contribute through better engineering practice. The centers are designed to build working relationships between university faculty and students and industry engineers and scientists and to meet a need for providing cross-disciplinary research opportunities for faculty and students. In April 1985, after considering 142 proposals from over 100 institutions in a wide range of topics, NSF made the first six ERC awards. Since then, NSF had made eight more awards. NSF supports the centers through its grants; however, the centers are expected to have a strong commitment from industry (money, equipment, and people) and, where appropriate, from state and local government. NSF has allocated a total of $100.2 million from fiscal year 1985 to fiscal year 1988, and centers reported receiving about $35.8 million from industry over that same period.

In keeping with its policy to evaluate each center every 3 years to determine whether to renew the center for another 5-year award, NSF has recently completed its evaluation of the first six ERCs, established in 1985, and on the basis of that evaluation has decided to renew support for four of them.

NSF's Selection, Monitoring, and Evaluation

Concerning NSF's criteria for selecting ERCs, we found that although it was not explicitly stated, research quality emerged as the most important criterion NSF used in awarding center grants and that only proposals rated high in research quality had a chance of receiving an award. Moreover, there appeared to be little, if any, trade-off during the selection process between research quality and any of the other selection criteria, such as its contribution to international competitiveness or engineering education. An unresolved issue concerns whether NSF, in its program announcements, should identify and seek proposals in specific research areas considered most important in furthering U.S. economic competitiveness. While such targeting could encourage proposals in particular areas, it is difficult to predict which technologies will be important to industry in the future.

NSF's monitoring system allows NSF to make yearly budget decisions through annual formal on-site visits. However, the system is still evolving, and program officials are trying to establish a data base and to use strategic plans to better oversee center activities.

NSF's approach is to evaluate each center, after 3 years of operation, on its progress in meeting ERC program goals. This type of evaluation is useful to NSF in deciding whether to renew the center's funding for another 5 years. However, it does not provide a sound basis for evaluating the strengths and weaknesses of the ERC approach because it does not compare the ERC approach with other approaches to engineering research and education. NSF considers it too early to do this type of evaluation of the ERC program.

Industry Reaction to ERC Program

Industries sponsoring ERCs ranged from automobiles and steel to biotechnology and semiconductors. Industrial participants generally responded favorably to the ERC program. Over half of them intended to continue participating in the ERCs for least 3 years and the ERC directors reported that most companies have kept their initial financial commitments. Although cross-disciplinary and joint research are goals of the ERC program, industry participants believe that the quality and type of research are more important reasons for sponsoring ERCs. In addition, although most of the participants sponsored university research before ERCs were established, interaction between university and industry personnel has increased since their establishment. However, industry sponsors reported that this interaction generally consists of contacts with ERC researchers and receipt of research documents rather than direct collaboration on research projects.

It is too early to tell how effective industry believes the education component of the ERCs is because industry has hired only a small number of ERC students. In the longer term, industry participants expect to benefit through better personnel recruitment and improvement of current personnel but not necessarily through receipt of patentable or commercialized products. Finally, many industry sponsors commented that an aspect of the program that needs to be strengthened or changed is their input to and influence on the ERC research agenda.

Agency Comments

NSF commented on a draft of this report. It found the evaluation beneficial and informative and had no major points of disagreement.

Objectives, Scope, and Methodology

To answer your questions about NSF's ERC program, we examined NSF's management of the ERC program, including its criteria for selecting, monitoring, and evaluating the ERCs. We had extensive discussions with NSF program officials concerning their management activities; spoke with panelists concerning their participation in the ERC selection process; and examined written documents, including the winning proposals and program guidance. In addition, we surveyed industry sponsors to obtain information and their views on various questions and issues, including why they were participating, whether they intended to continue to participate, and what types of industry/university interactions were occurring. We also surveyed center directors to get their perspective on the program and to relate information obtained from them with that obtained from the industry sponsors. Our work was conducted from July 1987 to May 1988.

Appendix I provides additional background information and details concerning our objectives, scope, and methodology. Appendixes II through VIII contain details regarding ERCs, NSF's relationship with them, and industry's reaction to them. Appendix IX contains agency comments. Major contributors to this report are listed in appendix X.

We are sending copies of this report to the Director of the National Science Foundation and other interested parties. Copies will also be made

available to others upon request. If you have any questions or if we can be of further assistance, please contact me at (202) 275-8545.

Flora H. Milans

Flora H. Milans
Associate Director

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Abbreviations

ERC	Engineering Research Center
GAO	General Accounting Office
MIT	Massachusetts Institute of Technology
NIH	National Institutes of Health
NRC	National Research Council
NSF	National Science Foundation
TAC	Technical Advisory Committee
UCLA	University of California, Los Angeles

Background

The goal of the Engineering Research Center (ERC) program is to develop fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry and prepare engineers to contribute through better engineering practice. In December 1983 the National Science Foundation (NSF) asked the National Academy of Engineering to conduct a brief study of the ERC concept, aimed at formulating guidelines for their mission, organization, operation, and funding. According to the National Academy of Engineering panel chairman, interest in creating a new form of university-based institution for engineering research resulted from a general recognition that several important national issues needed to be addressed, including (1) concern for the competitive disadvantage of some U.S. industries, (2) awareness that engineering disciplines directly supporting manufacturing lacked the technical capability and prestige of those supporting product design and development, (3) the need for an expanded engineering research effort, and (4) the desirability of strengthening the interaction between the academic and industrial communities.

The National Academy of Engineering issued the study results in February 1984, and in April 1984 NSF issued its first program announcement for the ERCs. NSF received 142 proposals from more than 100 universities in a wide range of fields. NSF announced awards for six ERCs in early April 1985. In 1936 NSF announced 5 more awards, and in 1987 it announced 3 more, for a total of 14 awards.[1] (See app. IV for a list of ERCs and app. V for a map of their locations.)

The 1985 program announcement defined ERCs with these three characteristics:

- ERCs should provide for working relations between university students and faculty and industry engineers and scientists.
- ERCs should emphasize the synthesis of engineering knowledge: they should seek to integrate different disciplines in order to bring together the requisite knowledge, methodologies, and tools to solve issues important to engineering practitioners.
- ERCs must contribute to the increased effectiveness of all levels of engineering education.

[1]The award to Duke University in 1987 was not completely funded until April 1988.

The 1986 program announcement added a fourth characteristic: the centers should have a strong commitment from industry (money, equipment, and people) to ensure its involvement in the research and educational aspects of the centers.

As the program has grown from 6 to 14 ERCs, NSF funding has increased from $10 million in fiscal year 1985 to $33.2 million in fiscal year 1988. NSF has allocated a total of $100.2 million from fiscal years 1985 to 1988. According to 13 of the ERCs (Duke University is not included), they received a total of about $35.8 million from industry over that same period. Industry contributions to ERCs, including dollars, personnel, and equipment, in fiscal year 1985 comprised from 8 to 50 percent of ERC budgets and in fiscal year 1988 comprised from 9 to 61 percent of ERC budgets. According to NSF, for the ERC program as a whole, NSF funds are matched by contributions from industry, state and local governments, and the university, with industry support roughly one-third of the total center support.

Objectives, Scope, and Methodology

On October 1, 1987, the Senate Committee on Commerce, Science, and Transportation asked us to assess two aspects of NSF's Engineering Research Center program. The first aspect concerned NSF's operation and evaluation of the ERC program. Specifically, the committee asked the following questions:

- What criteria does NSF use in selecting centers?
- What role does NSF play in the management and research agenda of a center once it is started (monitoring)?
- What methodology will NSF use in its own evaluation of the first centers, and what might that evaluation tell NSF and the Congress about the strengths and weaknesses of the ERC approach?

To answer the Committee's questions on NSF operation and evaluation of the ERC program, we interviewed NSF program officials, external peer reviewers NSF used in the selection process, evaluation experts, and managers of other federal and nonfederal center programs. We also examined written documents, including proposals and documentation of the winning proposals and other NSF program guidance. Because NSF was in the process of doing its third-year evaluation of the 1985 ERCs, we limited our review to examining NSF's approach in evaluating the ERCs, but we did not assess the results.

The second aspect the Committee asked us to examine was industry reaction to the ERC program. The Committee asked the following specific questions:

- What kinds of companies have supported engineering research centers? Do they include companies in basic industries as well as firms in new sectors?
- Have any companies dropped out or been unable to keep initial financial commitments?
- Do participating companies feel that the centers have helped them and their industries in terms of research, technological competitiveness, and the education of new engineers?
- Are there aspects of the centers' programs that the participants would like to see changed or strengthened?
- Do participating companies intend to continue their support?

To answer the Committee's questions on industrial participation, we developed two survey instruments—one to be sent to industry sponsors of ERCs and one to be sent to the ERCs themselves. Our methodology for the industry survey included asking each ERC for a list of its industry participants. At the time of our request, one 1987 center at the University of Colorado did not have any participants and another 1987 center, at Duke University had not been fully funded. Another center, at the University of Illinois, failed to provide a list of participants. Therefore we surveyed industry participants from 11 of the 14 centers.

In designing our industry survey instrument, we conducted open-ended interviews with representatives of companies that participate in the ERCs to get some idea of the types of responses we might get to the questions we planned to ask. After three pretests, we sent out the survey instrument to the entire universe of 203 company representatives. (See app. VI for a copy of the survey instrument.) We received 168 responses for an 83 percent response rate. One survey instrument was returned as undeliverable. Companies that support more than one center may be represented more than one time. However, the respondents in such cases generally represented different locations, divisions, groups, or departments of the same company.

The methodology for the center survey involved designing another survey instrument, pretesting it three times, and sending it to the 13

centers that had been fully funded. We received responses from all 13 centers. (See app. VII for a copy of the survey instrument.)

Our review was conducted from July 1987 to May 1988.

NSF's Management of the ERC Program

NSF manages the ERC program through its selection, monitoring, and evaluation activities. In the initial stages of the selection process, the criterion of research quality is emphasized; in the later stages, other criteria, such as economic competitiveness and management, generally receive more emphasis. In its monitoring process, NSF decides whether each ERC is operating according to its cooperative agreement and decides on the ERC's yearly budget. Because NSF's third-year evaluation process evaluates the ERCs on a center-by-center basis, it will not tell NSF or the Congress about the strengths and weaknesses of the ERC concept. However, NSF has used the process to decide which of the first six ERCs will be renewed.

ERC Selection Process

NSF selection criteria for the ERCs are similar to NSF's typical proposal evaluation and selection process. Most NSF awards, whether center awards or not, are the result of university scientists or engineers submitting written proposals to NSF which, in turn, are evaluated by a group of outside peers advisory to NSF. After the proposal review process, NSF makes the final funding decision.[1] Unlike the granting of most NSF awards, however, the ERC award is the result of a multi-step panel process and includes additional proposal evaluation criteria. (See fig. II.1.)

ERC Selection Criteria

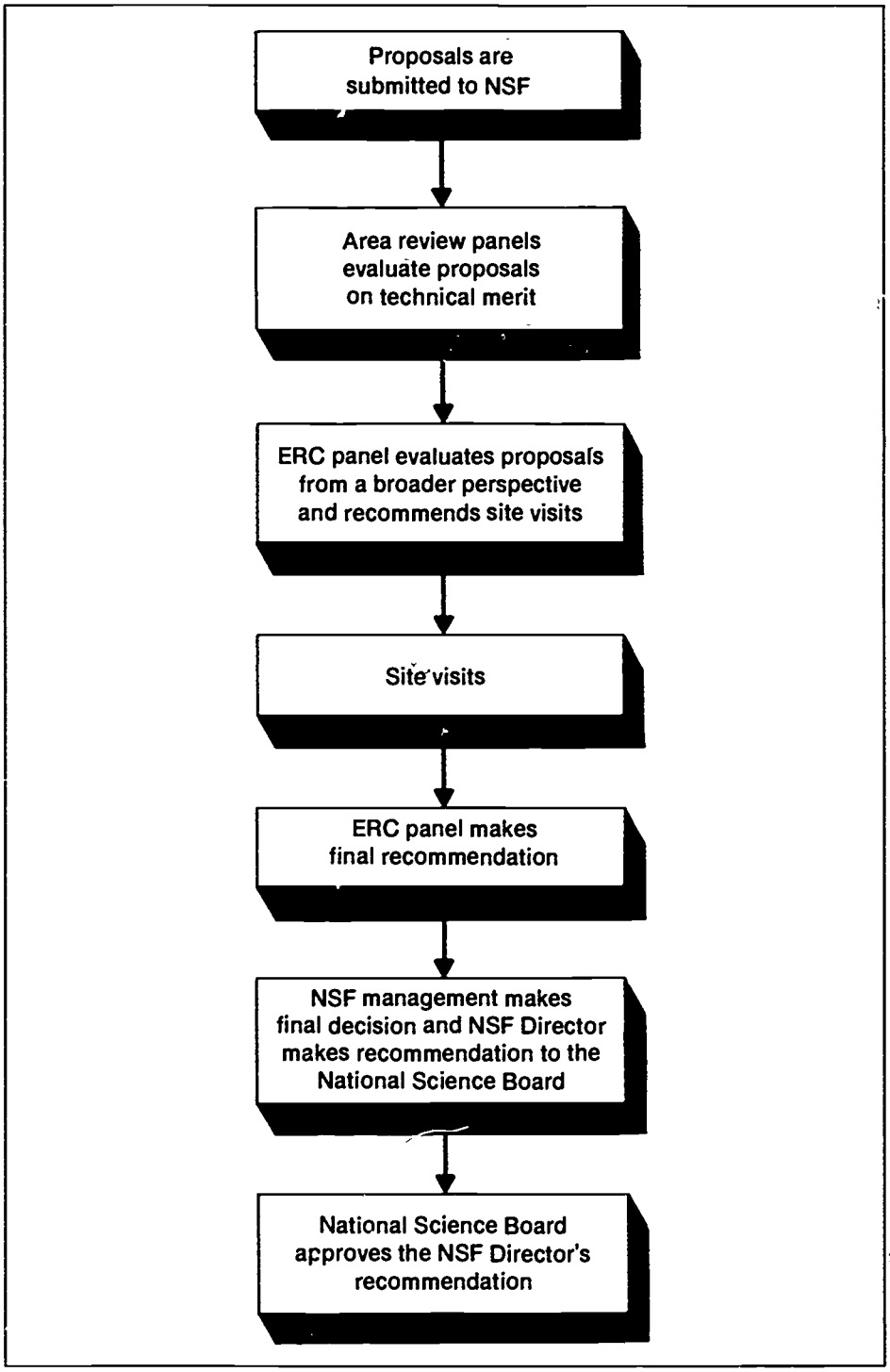
An NSF program official provided us with six criteria that serve as a basis for an external peer evaluation of ERC proposals. These criteria are derived from the description of the ERC program elements in the ERC program announcement:

Research and Research Team

- Is the research innovative and high quality?
- Will it lead to technological advances?
- Does it provide an integrated systems view?
- Is the research team appropriately cross-disciplinary?
- Is the quality of the faculty sufficient to achieve goals?

[1]See University Funding: Information on the Role of Peer Review at NSF and NIH (GAO/RCED-87-87FS, Mar. 26, 1987), for a description of the NSF process and criteria for awarding individual project grants.

Figure II.1: NSF's ERC Review Process



Source: NSF.

International Competitiveness	• Is the focus directed toward competitiveness or a national problem underlying competitiveness? • Will the planned advances serve as a basis for new/improved technology?
Education	• Does the center provide working relations between faculty and students and practicing engineers and scientists? • Are a significant number of graduates and undergraduates involved in cross-disciplinary research? • Are they exposed to a systems view of engineering? • Are there plans for new or improved course material generated from the center's work? • Are there effective plans for continuing education for practicing engineers?
Industrial Involvement/ Technology Transfer	• Will industrial engineers and scientists be actively involved in the planning, research, and educational activities of the ERC? • Is there a strong commitment or potential for a commitment for support from industry? • Are there new and timely methods for successful transfer of knowledge and developments to industry?
Management	• Will the management be active in organizing human and physical resources to achieve an effective ERC?
University Commitment	• Is there evidence of support and commitment to the ERC by the university? • Is there evidence that the tenure/reward practices will not deter successful cross-disciplinary collaboration? NSF staff, in addition to considering the advice and recommendations of peer reviewers, apply secondary criteria before making a final funding decision. These criteria are • geographic balance and distribution, • whether a university has already been granted an ERC, and • whether the research area complements the already existing centers.

Relative Importance of the Selection Criteria

NSF has stated that all six selection criteria are used in evaluating proposals for funding and that no weights are assigned the criteria. However, we found that some criteria receive more emphasis than others, depending on what stage in the selection process they are being considered. In addition, NSF program officials told us that overall research quality, as judged by the peer reviewers, is the most important consideration in selecting ERCs for funding. The following sections describe the stages of the process.

Area Review Panel: Emphasis on Technical Merit

Proposals are first reviewed by a panel of university and industry researchers, who are chosen primarily for their technical expertise.[2] The panels, which are organized by technical area, such as manufacturing, biotechnology, and materials, discuss the proposals using all the selection criteria but concentrate mostly on the criterion of research quality. These panels then group the proposals into three categories—highly recommended, recommended, and not recommended.

NSF program officials told us that a proposal has to be strong in all criteria to be put on the highly recommended list. However, we found that research quality is the most important criterion at this stage of the process and therefore is the most important criterion for being put on the highly recommended list. One program official told us that high marks on research quality is a "necessary, but not sufficient" condition for putting a proposal on the highly recommended list. According to this official, if the proposal meets this criterion and also meets all the other criteria, it makes the highly recommended list. However, if the proposal is very high in research quality but not as high on any of the four other areas, it will fall into the recommended list. And, if the proposal does not do well in research quality, regardless of how well it does in the other areas, it will not be recommended for funding by the preliminary panel. Research quality, therefore, is the major determinant, during the area review panel stage, of how a proposal is ranked for consideration by the second, or ERC, panel.

ERC Panel: Emphasis on Competitiveness and Other Criteria

Proposals are then reviewed from a more "strategic perspective" by the broader based ERC panel. The ERC panel consists of about 12 members who are mostly senior industrial research managers and academic leaders with significant experience in strategic research management and/or

[2]In 1987, for example, there were 68 proposals and 60 preliminary reviewers, who made up 5 panels (approximately 12 reviewers per panel), each of which reviewed 8 to 18 proposals.

university administration. This panel concentrates on those proposals highly recommended by the area review panel, but also reviews proposals the area review panel classified as recommended and not recommended. The ERC panel meets twice, first to recommend proposals for a site visit and second, after the site visit, to recommend proposals to NSF for award. As table II.1 shows, it is a winnowing down process.

Table II.1: Results of the Proposal Review Process

Year	Number of proposals	Highly recommended	Recommended	Not Recommended	Site visits	Recommended to NSF	Number awarded
1985	142	40	34	68	14	9	6
1986	102	25	38	39	15	7	5
1987	68	20	17	31	12	7	3
1988	66	19	16	31	8	6	[a]

[a]Not available.

According to NSF officials and ERC panel members we talked with, all the selection criteria are considered in evaluating proposals to be recommended for a site visit. An NSF program director told us that the panelists focus on the strengths and weaknesses of the proposal as a whole and that the site visit is aimed at verifying these strengths and weaknesses.

The 1987 selection process is an example of how research quality continues to be the most important criterion while other criteria, such as economic importance, may gain in emphasis. According to an NSF program official, during that year's selection process, about 10 proposals from the area review panels' recommended list were given extra consideration on the basis of their potential importance to manufacturing, but only one of these proposals was of sufficient potential to merit a recommendation for a site visit. One program official said that the ERC panel was concerned that so many of the proposals in manufacturing were not rated in the highly recommended category. A closer look at these proposals, according to this official, revealed to the ERC panel's satisfaction that these proposals were not of sufficiently high quality and therefore were not ranked the highest.

Post-Site Visit

After the site visit,[3] certain criteria begin to receive special emphasis, according to NSF staff and ERC panelists. One ERC panelist said that at the final stage, the competitive issue had to be clearly demonstrated. Another panel member said that the most important post-site visit criterion was the quality of the leadership. In addition, NSF program officials have observed that economic competitiveness receives more emphasis in the ERC panel. An ERC panel member also told us that economic competitiveness is most intensively discussed after the site visit, when the ERC panel is deciding on its final recommendations to NSF. At this point the panel is typically considering 8 to 14 proposals and will recommend 4 to 9.

Final Funding Decision and Secondary Criteria

After the ERC panel has made its final recommendation, NSF staff review the proposals and make their final recommendation to the National Science Board for approval. Before a final decision is made, however, NSF may apply secondary criteria, such as geographic balance or institutional duplication. Concerning the criterion of awarding more than one ERC per university, an ERC program manager said that an ERC will be awarded to a school that already has one only if that award is the "best of the best."

According to an ERC program manager, program officials at the NSF division level recommend proposals for funding, taking into consideration outside peer review, the secondary criteria, and available resources. These recommendations are reviewed by the Division Director, the Assistant Director for the Directorate, and the NSF Director. The NSF Director, after concurring, recommends the selection to the National Science Board. The Board approves the Director's recommendation.

The NSF Director and/or the National Science Board may sometimes introduce a new dimension to funding decisions. For example, when a proposal for biomedical engineering research from Duke University went before the Board for approval, it was the Director's recommendation to the Board that consideration be given to approval on condition that Duke receive co-funding from another federal agency, the National Institutes of Health (NIH). NSF provided partial support to the ERC, and in September 1987 Duke submitted a program project grant application to NIH. In April 1988 it withdrew the grant application because it had

[3]Site visits involve two to three ERC panelists, three to four consultants selected for technical emphasis (peer reviewers), and one to two NSF staff members. There are between 8 and 15 site visits a year, according to officials.

received feedback that its projects were not ready for clinical validation. In the meantime, three groups of ERC researchers had received NIH grants for medical/physiological engineering research at the ERC. As a result, NSF decided that these grants could be considered as fulfilling the Board's requirement for one-third support from NIH. NSF awarded funds to continue the ERC.

Assessing Potential Key Research Areas of Technological Growth

A question that arises in a program with the ultimate goal of international competition is the extent to which NSF assesses and seeks proposals in research areas particularly relevant to future competitiveness. NSF's policy has been, and remains for the most part, to let the research community, through proposal submission, decide the key areas with potential for technological growth. In this regard, NSF requires that the proposal state how the proposed research area is important in terms of its impact on technological advancement and long-term competitiveness. NSF adhered to this policy of letting the proposer justify the economic importance of the research area for the second and third years of the ERC program, when NSF did not list areas in the program announcements.

The 1985 program announcement did list areas, but, according to NSF officials, only to suggest the breadth of topics desired, not to predetermine technological targets. The 1988 program announcement also listed areas that were based on NSF's assessment of their economic potential.[4] Although both announcements list technological areas, they are not ranked, and NSF refers to them in the program announcement as suggested areas. An unranked, nonexclusive list of general technology areas appears to be as far as NSF has been willing to go to identify in advance areas potentially important to economic competitiveness.

National Research Council Assessment of the ERC Selection Process

The National Research Council (NRC), which has published independent studies for NSF on various aspects of the ERC program, recommended in a 1988 study of the ERC selection process that, among other things, NSF annually assess the potentially high pay-off research areas. This yearly assessment will, in the report's words, ". . . provide a firmer basis for specifying topic areas in the Program Announcement. The resulting

[4]The 1985 announcement listed systems for data and communication, computer-integrated manufacturing, computer graphics design, biotechnology processing, materials processing, transportation, and construction. The 1988 program announcement listed five broad technology areas: design and manufacturing, advanced material processing, surface and interfacial technologies, resource recovery and utilization, and emerging technologies (e.g., neuroengineering, biotechnology, lightwave technology, optoelectronic mechanical devices and systems, etc.).

assessments and forecasts could then be summarized and sent to reviewers in the initial mailing, for use in selecting proposals."

This recommendation is stated as an interim substitute for developing a framework or criteria for establishing desirable areas of focus or for judging proposals in terms of their economic potential, which NRC says may be impossible to do.

NRC also recommended that any topics listed in the program announcement should be "clearly stated and relatively specific. For example, 'emerging technologies' and 'design and manufacturing' are so broad that they may attract a number of proposals whose topics have little chance of receiving funding."

Advantages and Disadvantages of Specifying Key Technological Areas

The following are some advantages of specifying key technological areas:

- In a program whose ultimate goal is enhancing competitiveness, specifying areas in advance could keep the focus on competitiveness because these areas would be determined by an assessment of what areas potentially have the greatest economic impact. In this regard, NRC's 1988 report recommended that NSF sharpen its focus on competitiveness by sponsoring an annual workshop to identify areas of emerging technological opportunity and to compile these areas for the proposal reviewers. In addition, NRC cautioned NSF that any listed topics should be specific and clearly stated. NRC also said that "it would be highly useful to have a framework or a set of agreed-upon criteria for establishing desirable areas of focus and judging proposals in terms of their economic potential . . ."
- The Commerce Department has attempted economic impact assessments that NSF could use as a frame of reference not only for future selections but also for past awards. The Commerce study, The Status of Emerging Technologies: An Economic/Technological Assessment to the Year 2000 (June 1987) creates a typology of technology areas and ranks them in three groups, depending upon the degree of their perceived future economic impact. Commerce makes clear that the list is not "cast in concrete" since the recent breakthrough in superconductivity shows that emerging areas are hard to predict. However, this study shows that a simple typology and ranking of technologies is possible.
- In an awards system that involves a wide discrepancy between the number of proposals submitted and the number of awards made (success ratio is between 4 percent and 5 percent), specifying areas could

not only service the goal of competitiveness but also limit the number of competing proposals (assuming the areas were specific enough), thereby eliminating proposals that ordinarily would not have a chance of being funded because they are in areas deemed not important enough.

The following are some disadvantages of specifying areas:

- Targeting areas most important to economic competition is difficult. The NRC report, even though it recommended that NSF assess areas, admitted that creating a framework or set of agreed-upon criteria for establishing areas may be impossible. In addition, a state science and technology program manager and a business professor told us that it is very difficult to predict which technologies will be important to industry in the future.
- An area designated highest on the ranking of economically important areas may not carry with it a research plan of high enough quality. As the NRC report states, a balance must be struck between the quality of the research and the quality of the proposed area. Another danger, according to an NSF program manager, is that there may not be a scientific group performing with appropriately high quality ready or available to undertake an ERC.

NSF Monitoring of ERCs

The purpose of NSF's monitoring is to help ensure effective center performance and administration. One feature of monitoring is a yearly site visit and review, which is a basis for determining yearly budget levels. NSF is in the process of making changes in the monitoring activities, such as establishing center expectations on a yearly basis and requiring outside reviewers for the yearly site review.

Cooperative Agreements and Yearly Review

Although no written criteria exist for how NSF should monitor the ERCs, NSF's monitoring activities are listed in each center's cooperative agreement. The cooperative agreement describes funding amounts and schedules, various reporting requirements, special requirements for the particular center, and joint NSF-awardee activities. For example, NSF requires under the cooperative agreement that in 1987 each center submit a long-range research plan, called a strategic plan, detailing how it will carry out its work and within what time frames. Each ERC is also required to hold annual meetings with industry and with other centers and to keep a data base in order to provide NSF with quantitative indicators of its activities and progress in meeting program goals. The agreement also states that continued NSF support will depend, among other things, on an annual review of ERC progress.

Each NSF program officer monitors three to four centers. Besides the specific activities mentioned in each center's cooperative agreement, NSF program managers told us they make ad hoc visits to the center and call the ERCs frequently, if necessary. The intensity with which NSF monitors a center often depends on the situation at that particular center. For example, one program officer said that, because one of his ERCs was having problems, he checked in with it about every 2 weeks.

One of the major roles of the program officer is to conduct a yearly site review of the center using internal NSF staff and to recommend to the center director improvements in operation that are based on this review. One ERC program director told us, for example, that the review team, or Technical Advisory Committee (TAC),[5] is at the center for 2 days, talking with faculty, university administrators, students, and industry officials, as well as visiting lab facilities.

The TAC team chairman writes a report[6] advisory to the ERC program director, and on the basis of this report, the program director may make specific recommendations to the center director for improvements. According to one program director, the cooperative agreement is the "teeth" connected to the yearly site visit. For example, NSF cut the budget of one center intentionally because, as a result of the yearly site visit, it found that the center was not following certain key ERC program goals. The message was that the budget would be restored if the center followed up on the site visit recommendation. According to a program official, the center followed up on the recommendations and the budget was restored.

NSF Oversight of ERC Research

NSF has started to keep track of the research performed at each center by requiring the ERCs to submit a strategic research plan. NSF initiated this oversight mechanism in March 1987 because, according to an ERC program manager, early TAC visits began to point to a lack of focus and a lack of project integration. In addition, a group of industrial advisors to the ERCs was brought together at NSF in February 1987 to discuss overall progress of the ERCs. According to an NSF program official, industry

[5]The TAC team is chaired by an NSF program official chosen by the ERC program director and may include NSF staff, scientists from industrial laboratories, and faculty members of universities.

[6]NSF guidance states that the TAC report should address the following: (1) management of the ERC and its leadership, (2) the quality of the research program, (3) the educational program with particular response to undergraduate education, (4) the extent and reality of industrial participation, (5) the extent and reality of state and university support, and (6) specific comments and recommendations to the program director for improvement of the ERC program.

advisors wanted the ERCs to focus on specific goals for technological advancement. They felt that long-term industrial involvement in the ERCs to the extent envisioned by the ERC concept required more output, such as prototypes, than students and knowledge advances.

According to one program director, the strategic plans become a framework for selecting individual projects. He also said that these plans reflect the industries' need for deliverables and the researchers' need for freedom to pursue individual research interests.

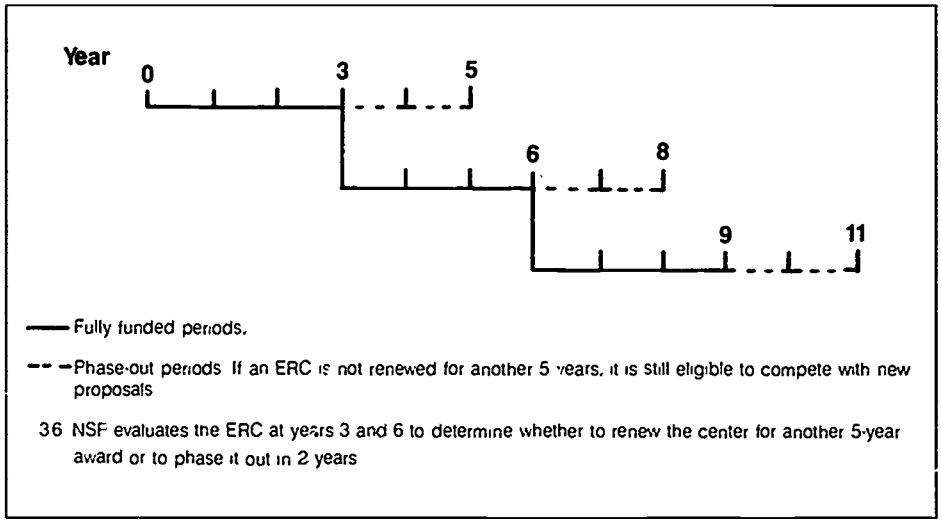
NSF has also set up a data base of indicators of ERC activities. The data base is supposed to contain information submitted by the ERCs, such as the industry role, center thrust areas,[7] research projects, and personnel involved in research. However, not all ERCs provided the data, and, according to the program official in charge of the data base, some of the data were inconsistent or incorrect. For example, he received data from one center that were inconsistent with data in its annual report and with data it had previously provided. In addition, several program directors told us that their use of the data base for monitoring the ERCs was limited by the incompleteness of the data or by the type of data collected. The program's deputy director told us that she uses the data to respond to questions on the amount of funds received by the ERCs from industry and other sources and to determine whether the faculty is working in a cross-disciplinary manner by the number and disciplines of faculty participating in the ERC.

NSF Evaluation Process

NSF evaluates each center every 3 years to decide whether to renew the center for another 5-year period. The NSF evaluation is an assessment both of the last 3 years and of future potential based on the ERC's renewal proposal. According to evaluation materials, the evaluation occurs within too short a time to establish the impact of the centers on technological advances and education but within enough time to judge some directional change. Because the third-year evaluation is on a center-by-center basis, it will not answer the Committee's question on the strengths and weaknesses of the ERC approach compared with other types of funding mechanisms. Figure II.2 shows the life cycle of an ERC.

[7]A thrust area is an area of research into which a group of research projects with similar goals are organized.

Figure II.2: Life Cycle of an ERC



Source: NSF.

Third-Year Evaluation Criteria

The criteria that NSF has established to evaluate each center come from the program announcement, the cooperative agreement, and the study on evaluation that was done for NSF in 1986 by NRC. These criteria are similar to those NSF has established to select centers. They are

- research, including competitive focus;
- education;
- industrial collaboration;
- leadership and management; and
- university climate.

According to an ERC program manager, as with the selection criteria, the criteria are not numerically weighted. However, according to this official, the three primary criteria for evaluation are research quality, education, and industrial collaboration.

According to program documents, the criteria given to the peer evaluators are meant to be a frame of reference upon which to build informed judgments and recommendations, not a "cookbook" or formula approach. NSF's written guidance to the peer reviewers on using the criteria and writing a site visit report states that:

"It is not intended that an evaluation/review report merely be answers to these questions. Rather the report should reflect the judgement of the team regarding the progress and prospects of the ERC using these criteria as a frame of reference. They

are intended to bring the reviewer up to speed on the goals and objectives of the ERC program."

NSF guidance also states that the application of the criteria to each center may differ:

"depending upon whether or not the ERC was built upon an existing center or it started de novo [anew], the degree of difficulty inherent in the focus of the center, the degree of difficulty inherent in the blending of the disciplines involved in the ERC, the degree of sophistication of the targeted industrial community, etc."

NSF also gave the peer reviewers quantitative profiles of some of the centers at the plenary session, but did not specify how it wanted the reviewers to use these data in evaluating the centers. The ERC program manager said that NSF was working on ways to tie the quantitative data to the third-year evaluation in a more meaningful way after a longer period of data collection has occurred for a larger number of centers.

Third-Year Evaluation Procedures

In March 1988 NSF completed its third-year evaluation of the six ERCs awarded in 1985. This process began in March 1987 when ERC program officials mailed the third-year renewal proposal format and review criteria to the ERCs. In July and August 1987, evaluation teams[8] were finalized and NSF program officials mailed to evaluators a package of materials to study before making their site visits. These materials included the ERC program announcement, NSF decision documents justifying awarding the ERC, evaluation/review guidelines, and each center's renewal proposal. The reviewers met a month later in a plenary session and NSF program staff gave them more materials, such as the original proposal and TAC reviews, annual reports, and other information clarifying the evaluation criteria.

At this meeting, NSF program officials explained the program goals and evaluation criteria to develop a uniform base of information across the entire set of reviewers. They also gave specific illustrations of the ways in which existing centers were meeting them. Centers met the education component, for instance, with curriculum development; new or modified courses/texts; involvement in cross-disciplinary team research; and activities, such as seminars and workshops, to give a systems view.

[8]Each evaluation team has five to six members, of which approximately half are from industry and half from academia.

Program management also identified overall factors for the third-year evaluation:

- Has the ERC met its goals and the ERC program goals?
- Is the ERC cohesive with shared goals?
- Is it an ERC or business as usual?
- What has the ERC achieved that could not be achieved through individual grants?

According to a program official, a team of evaluators made a 2-day site visit to the center, wrote a site review report that was based on NSF guidelines, and made a recommendation to the program director on whether the center, in the team's judgment, should be renewed. The team was instructed to consider recommendations for 5-year unconditional renewal, 5-year conditional renewal, or termination after 2 years. According to program management, the guidance for choosing one of these options is

- unconditional 5-year renewal if the center is strong in all criteria,
- conditional 5-year renewal if the center is strong in some of the criteria and weak in others, or
- no renewal and phase-out if the center has failed in the three most important areas (research, industrial collaboration, and education).

According to the ERC program manager, the NSF program director responsible for each center reviewed the site-team recommendation and may have conferred with the center for clarification. Then the program director made his/her recommendation to the division director for the ERC program; the division director, in turn, made his recommendation to the director of the engineering directorate, who, in turn, made his recommendation to the NSF Director. The NSF Director presented his recommendation to the National Science Board for its approval.

The National Science Board acted on NSF's decision regarding the renewal of the first six centers in March 1988. The Board announced that four ERCs would receive new 5-year awards: Columbia University, Massachusetts Institute of Technology (MIT), Purdue University, and University of Maryland/Harvard University. The two centers that were not renewed were the University of Delaware and the University of California at Santa Barbara. NSF officials told us that the ERC at the University of Delaware devoted insufficient attention to research in composites manufacturing, its designated area of research, and that the ERC at the University of California, Santa Barbara, was weak in arriving at a

coherent focus over the course of center operations, and its prospects for developing a high-quality research effort in the next 3 to 5 years did not warrant a renewal.

The ERC program manager said that the third-year evaluation is evolutionary and that before the next evaluation is conducted for the 1986 class of ERCs, program officials plan to conduct a survey of the reviewers and centers on the evaluation process as it was conducted for the first class of centers.

Conclusions

Although NSF has not explicitly stated, as either guidance to the peer reviewers or policy, that some criteria are more important than others, it has structured the proposal evaluation and selection process in such a way that (1) research quality emerges as the prime criterion in funding centers and (2) only among those proposals first judged as the best primarily in terms of research quality are the other selection criteria more intensively discussed. Moreover, there appears to be little if any trade-off between research quality and any of the other selection criteria during the course of the selection process.

In addition, it is unclear whether targeting key technological growth areas is either practical or desirable in trying to further the ERC concept. While such targeting could encourage proposals in the particular areas, predicting those areas that will be important to industry in the future is difficult.

NSF's monitoring system seems to be designed to allow NSF to make yearly budget decisions for each center on the basis of the extent to which each center is meeting program goals. However, the monitoring system is still evolving. Some unresolved areas include

- collecting consistent and correct quantitative data from all centers for the ERC data base,
- integrating quantitative data into its monitoring and evaluation processes, and
- determining the effectiveness of the new strategic plans.

NSF evaluates the centers on a center-by-center basis to decide whether to renew a center's funding for another 5 years. The current evaluation system can be described as process-oriented rather than outcome-oriented because it focuses on directional change, rather than impact. The evaluation does not provide a sound basis for evaluating the strengths

and weaknesses of the ERC approach because it does not compare it with other approaches to engineering research and education. NSF considers it too early to do this type of evaluation of the ERC program.

Results of Industry and Center Surveys

To answer the Committee's concerns about industry participation in ERCs, we surveyed industry sponsors for their views on the ERC program. We divided our survey into three issues: (1) what motivates a company to participate in an ERC and whether the company anticipates continuing its participation, (2) how companies interact with ERCs, and (3) how technology is transferred from the ERC to the industry sponsors. We also asked the participants for some background information on their companies. In addition, we surveyed the ERCs to answer concerns raised by the Committee that could only be answered by the ERCs and to determine whether ERCs are aware of industry expectations.

In general, our survey of industry participants showed that the quality and type of research is what motivates companies to participate in the ERCs and that industry anticipates continued participation. Although a majority of companies sponsored university research before the ERCs were established, industry/university interaction has increased since the establishment of the ERC. However, this interaction is not generally through direct collaboration on research projects. Although participants reported receiving results of ERC research, a majority of companies said that they have never continued, or it was too early to tell if they would continue, ERC research at their labs but that they might do so in the future. It was also too early to determine what benefits the industry believes it is receiving from the engineering education aspects of the ERC program.

ERC participants included a wide variety of companies from heavy industry, such as automobiles and steel, to new companies in high technology areas, such as biotechnology processing and semiconductors.

Motivation for Participating in an ERC and Continuing Support

The first issue we looked at was why companies were participating in ERCs and whether they intended to continue their participation. We asked company sponsors how important various reasons, including research quality and joint and cross-disciplinary research, were for participating in an ERC. These reasons related to NSF's program objectives and characteristics as stated in the ERC program announcement. Generally, industry respondents rated type and quality of research as extremely to very important reasons for participating in an ERC, and rated cross-disciplinary and joint research as very to moderately important reasons for participating. Respondents indicated that they intend to continue in the ERC program beyond 1 year.

Importance of Type and Quality of ERC Research

We wanted to know how important reasons, such as the type and quality of the research, were to a participant. On a scale of extremely important to not at all important, the majority of industry participants rated research matching company interest (89 percent) and quality of knowledge and researchers (88 percent) as extremely to very important reasons for participating in an ERC. Center affiliation did not seem to affect responses. (See figs. III.1 and III.2.) In addition, a majority of participants rated access to research results (73 percent) and state-of-the art research that interests the company (88 percent) as extremely to very important reasons for participating in an ERC.

Figure III.1: Reasons for Participating in ERCs: Research Matches Company Interests

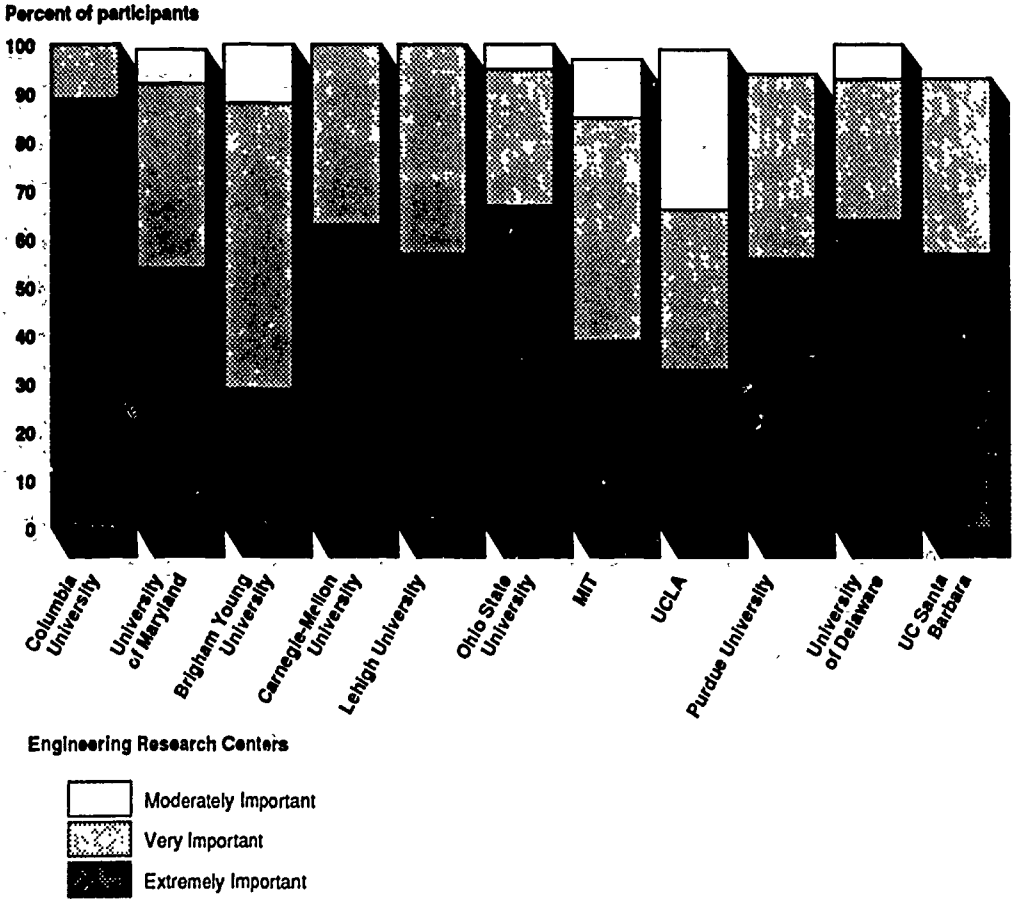
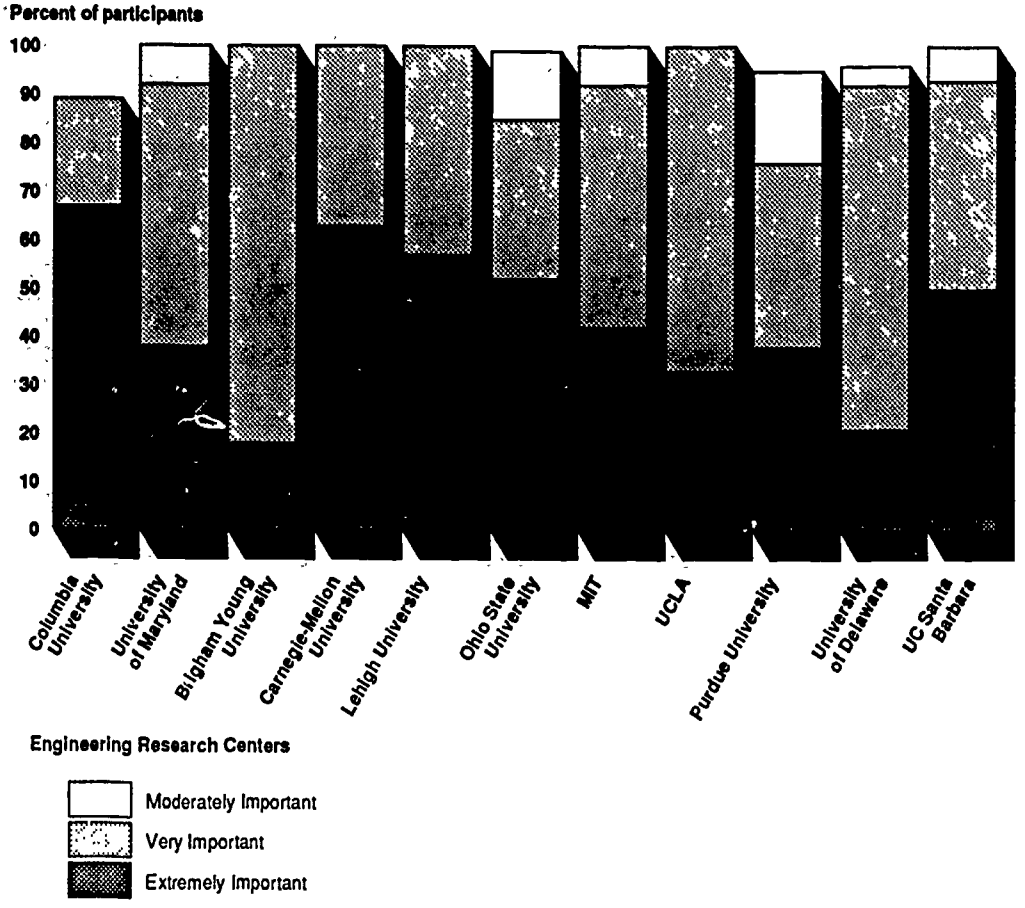


Figure III.2: Reasons for Participating in ERCs: Quality of Knowledge And/Or Researchers at ERC



Importance of Joint and Cross-Disciplinary Research

Two characteristics of ERCs, as stated in the NSF program announcement, are that they

- provide for working relations between university students and faculty and practicing engineers and scientists—in other words, joint research, and
- seek to integrate different disciplines to bring together the requisite knowledge, methodologies, and tools to solve issues important to engineering practitioners—in other words, cross-disciplinary research.

We wanted to know how important these were to industries in motivating them to participate in the ERCs. Participants rated opportunity for joint research (63 percent) and opportunity for cross-disciplinary research (58 percent) as very to moderately important. (See figs. III.3 and III.4.) Center affiliation did have some effect on the responses to the importance of the opportunity for joint research and the opportunity for cross-disciplinary research, as shown in the following examples:

- Only 3 of 26 participants in the MIT ERC and only 5 of 17 participants in the Brigham Young University ERC believed that opportunity for joint research was a very important reason for participating in the ERC. None of the participants in these centers believed that opportunity for joint research was extremely important.
- Only 6 of 28 participants in the University of Delaware ERC and only 5 of 26 participants in the MIT ERC believed that opportunity for cross-disciplinary research was a very important reason for participating in the ERC.

When participants were asked specifically about cross-disciplinary research, 85 percent believed the center had done research they would consider cross-disciplinary. About 50 percent believed the cross-disciplinary research was of a moderate to very great benefit to them. Two participants commented on this area as an aspect they would like to see strengthened or changed. One commented that he wanted more interdisciplinary emphasis and another commented that he wanted more effective interdisciplinary research.

Other Reasons for Participating

As for other reasons for participating in the ERCs, 57 percent of the participants rated opportunity to develop new research projects as very to moderately important, 64 percent rated access to students trained at the ERC as very to moderately important, and 36 percent rated proximity to the ERC as very to moderately important. The opportunity to develop patentable products was rated somewhat to not at all important by 73 percent of the respondents.

Center Director Responses

We asked the ERC directors how important the same reasons were for attracting industrial sponsors to their centers to determine whether they were aware of industry expectations. We compared the responses from industries affiliated with a specific center with the responses provided by the center director. The results were mixed for some answers. How-

ever, for the questions on quality and type of research, the center directors generally judged these to be extremely to very important reasons for attracting industry to their centers. These responses were in line with industry responses.

Figure III.3: Reasons for Participating in ERCs: Opportunity for Joint Research

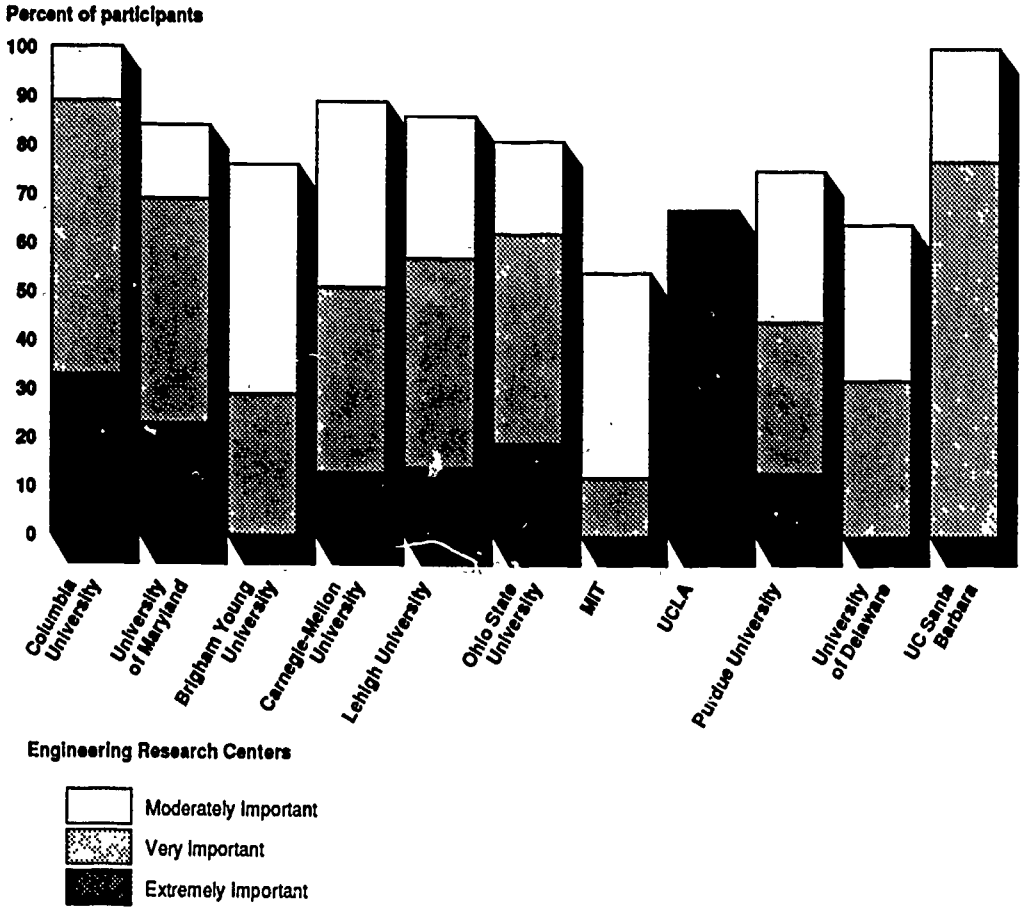
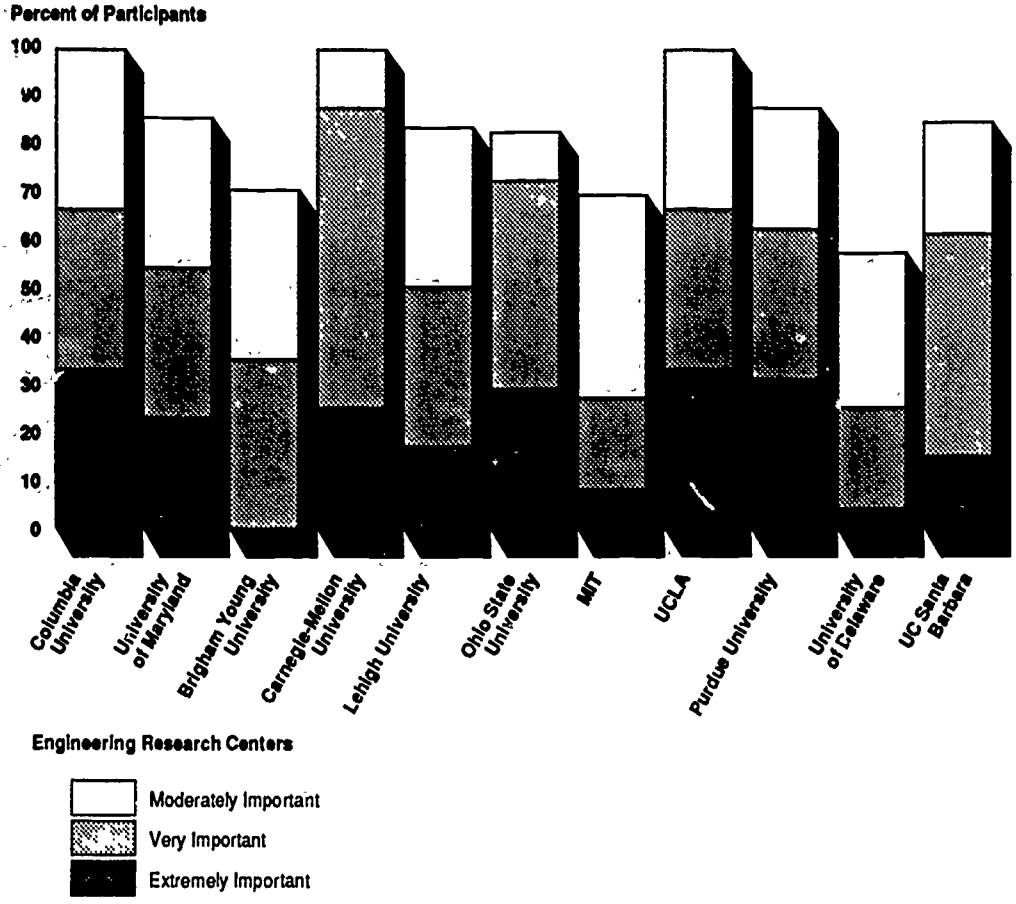


Figure III.4: Reasons for Participating in ERCs: Opportunity for Cross-Disciplinary Research



Industry Intentions to Continue Support

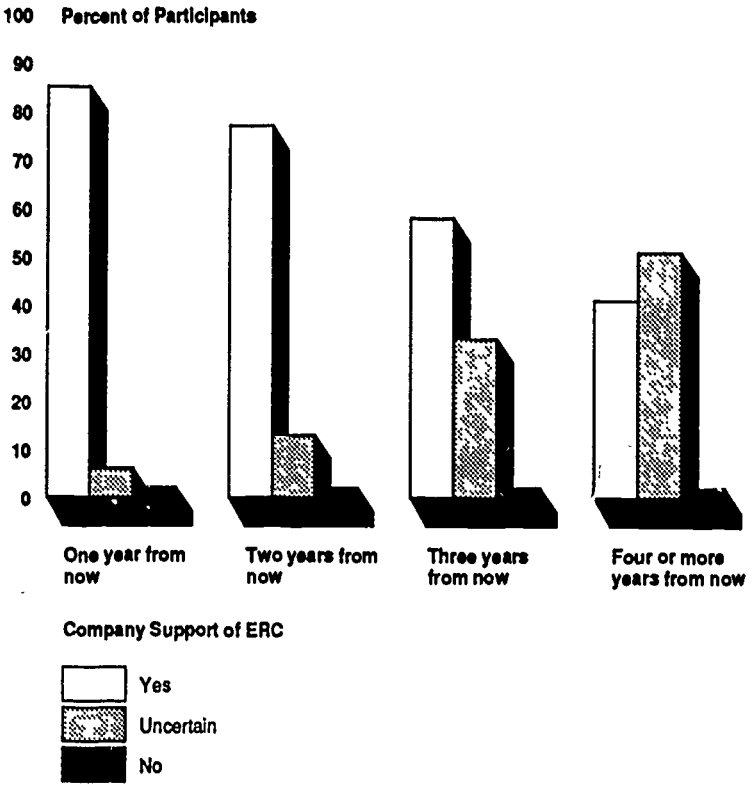
Participating companies indicated that they intend to continue supporting the ERCs.

- About 85 percent of the respondents indicated that they would definitely or probably support the center a year from now. Over 75 percent

said they would definitely or probably support the center 2 years from now.

- The percentage of those uncertain about continued participation rose as the number of years of future support rose. Over 50 percent were uncertain whether they would support the center 4 or more years from now.
- About 84 percent of those expecting to support the center 1 or more years from now expected to do so at the same level as the current year. (See fig. III.5.)

Figure III.5: Industry Responses on Continuing Support of ERCs



Note: Totals do not add to 100 percent because of missing responses.

Of the 13 ERCs, only 4 reported that from 1985 to 1987, 10 companies were unable to keep their financial commitments for a total of $193,000. Table III.1 shows this breakdown in relation to all companies providing support to these ERCs during this period.

Table III.1: Number of Companies Unable to Meet Financial Commitment, by Year

Year	Number of ERCs[a]	Participating companies	Total received from industry	Companies unable to meet financial commitment	Amount
1985	1	9	$281,000	1	$20,000
1986	2	33	$1,283,000	4	$35,000
1987	2	42	$1,473,000	5	$138,000

[a]One ERC reported companies unable to meet financial commitments for 2 fiscal years.

Engineering Education and Industry/ University Interaction

Another characteristic of the ERC program, as stated in the program announcement, is that the program should contribute to the increased effectiveness of all levels of engineering education. Because the program is still in its infancy, not many students have been hired, so the evidence of the benefits of ERC education are not conclusive. A goal of the ERC program is to develop fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry. Our survey showed that an overwhelming majority of companies participating in the ERCs have had previous experience with the researchers at the ERC before it was established and have supported university research for more than 5 years. In addition, although industry is expected to benefit from the research at the ERCs, a majority of industry participants believe they have only some to little or no influence on ERC research agendas.

Engineering Education

A goal of the ERC program is to strengthen undergraduate and graduate education. About 20 percent of the respondents said they had hired students that had graduated from the ERC. Of those hired, 36 were graduates and 38 were undergraduates. In the opinion of these participants, the preparation of the ERC graduate compared with that of traditional engineering school graduates was somewhat better in knowledge of state-of-the-art equipment (58 percent) and knowledge of areas in which the company is specifically interested (49 percent).

In commenting on aspects they would like to see strengthened or changed, several participants mentioned the area of graduate student training. One wanted more emphasis on graduate student training and another wanted greater involvement of industry-based graduate students in ERC activities. Several commented on the need for increased participation by students who are U.S. citizens. One suggested that the ability to draw top American students for graduate studies as part of

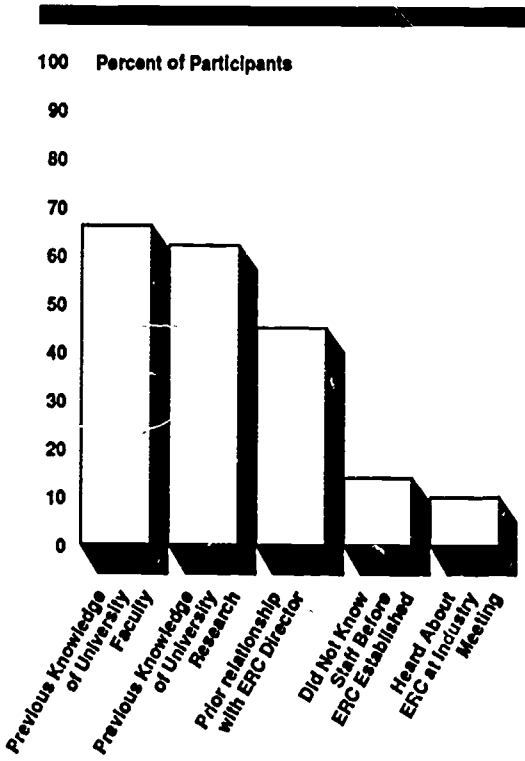
the ERC could be strengthened by providing more funds for fellowships and graduate assistants at levels comparable to industrial salaries.

Prior Industry Involvement in University Research

Company participants indicated that they became aware of ERCs in a variety of ways, although the most common way was through previous knowledge of either the university faculty or the research. (See fig. III.6.)

- About 66 percent of the respondents had previous knowledge of the faculty, 62 percent had previous knowledge of research at the university, and 45 percent had a prior relationship with the center's research director before the center was established.
- About 14 percent were approached by the center staff without previously knowing them and 10 percent heard about the ERC at an annual industry meeting.

Figure III.6: How Company Sponsors Found Out About ERC



Note: Respondents could check more than one response.

Company participants with previous university research experience were most likely to participate in the ERC.

- Over 68 percent of participants that reported having sponsored university research for 5 or more years had previous knowledge of research or faculty at the university or a prior relationship with the center's director.
- Of the 24 respondents that had no previous knowledge of the center, 17, or 70 percent, had sponsored some university research for 5 or more years.

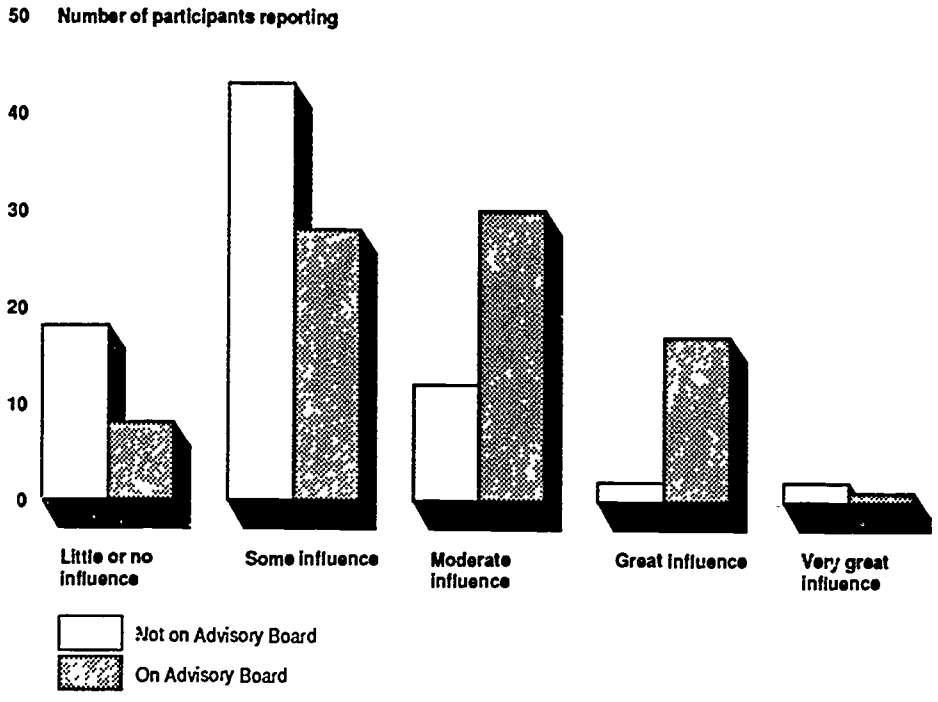
Participants that had a relationship with the university before the establishment of the ERC have continued that relationship after the establishment of the ERC. Over 50 percent of the participants who interacted with the same university personnel before and after the ERC was established reported no change in use of the university for such activities as contracts for research projects, general support of faculty research, support of student thesis research, providing company personnel as adjunct faculty, and having graduate or undergraduate students working at the company.

Influence on ERC Research Agenda

Although industry is supposed to participate in the ERC to focus the activities on current and projected industrial needs, over 57 percent of the participants believed they had little or no influence to some influence on the ERC's research agenda. Those participants that were on the ERC advisory board believed they had a greater influence on the ERC research agenda. (See fig. III.7.)

- Of the 84 participants reporting participation on an ERC advisory board, 48, or 57 percent, reported that, on a scale of very great to little or no influence, their influence on the ERC research agenda was moderate to very great.
- Of the 77 participants not reporting participation on an ERC advisory board, only 16, or 21 percent, reported that their influence on the ERC research agenda was moderate to very great.

Figure III.7: Influence of Industrial Sponsors on ERC Research Agenda by Participation on ERC Advisory Board



Center directors reported that industry had a greater influence on the centers' research agenda as the centers matured. On a scale of very great influence to little or no influence, for fiscal year 1985, 4 out of 6 centers reported some influence on their research agenda; for fiscal year 1986, 7 out of 11 reported moderate influence on their research agenda; and for fiscal year 1987, of the 13 centers, 6 reported moderate influence, 6 reported great influence, and 1 reported very great influence on their research agenda.

Center directors reported that industry influenced their agendas through several means. Twelve of the 13 directors cited advisory councils, committees, and boards as means by which industry influences their agendas. Other means mentioned included working groups, project review committees, annual associates meetings, specific discussions and individual contacts between industry technical personnel and ERC personnel, and workshops and conferences.

Participants had many comments in the areas of ERC research agenda and industry input. One participant commented that he would like to see

more influence from member companies and another expressed a desire for more direct input from industry that would influence research being performed and more direct critique of research progress. Other aspects that participants would like to see strengthened or changed included

- more requests for input from the company on the important research topics for ERC projects and
- increased interaction between ERC officials and top company leadership on overall technical direction and policy issues.

Many participants expressed a desire for more applied research. One wanted more emphasis on processes themselves as research projects and another wanted more emphasis on manufacturing engineering. Others stated the following:

- Many projects are for research only relative to theory, and the ERC needs more practical research and needs to be aware of state of the art already existing in industry.
- The ERC should be more realistic as to what is going on inside the industry and should direct its research to have a critical impact on the industry with its research and development program.

A few participants commented on the need for planning to meet industry needs. One participant commented that the ERC needed better focus on strategic and tactical technical plans relating to company needs.

Information Exchange

Participants received information from centers in various forms. The most often reported form of information was newsletters on ERC activities and research (85 percent), followed by progress or technical reports on research (79 percent), and seminar papers (58 percent). Several participants commented on the need for increased communication and reports from the ERC, including

- more frequent research reports;
- more information on research in progress; and
- periodic updates on research programs, perhaps quarterly.

We asked center directors about ERC activities in the past 12 months that involved interaction with industry sponsors. All 13 directors reported that their centers held events such as technical seminars, workshops, and symposia that industry sponsors had attended, and 5 reported holding these events 16 or more times. All center directors also reported

holding advisory panel or committee meetings for industry sponsors, providing information to industry sponsors on students studying at the ERC, and initiating joint research at the center with industry sponsors. Issuing newsletters on center activities to industry sponsors and issuing technical reports on results of research sponsored by industry were two methods for informing industry sponsors of center activities.

Although all the center directors reported holding workshops, five participants stated that they wanted more workshops.

Collaboration, Research Results, and Technology Transfer

Although our survey showed that contact with university research personnel has increased, survey responses showed little evidence of direct collaboration as indicated by the small number of participants reporting collaboration on research projects either on-site at company labs or at the ERCs. Most interaction takes place through discussion with the researchers and through technical and seminar reports. One reason for industry/university collaboration is enhanced international competitiveness. Most of the participants reported receiving some results of research performed at the ERC. Because the program is in its infancy, it is too early to assess the technology transfer aspects of the program. Some respondents indicated evidence of technology transfer; however, a majority of participants responded that either it is too early to continue, or they have never continued, an ERC research project at their labs, but they may in the future.

Increased Industry/ University Contacts

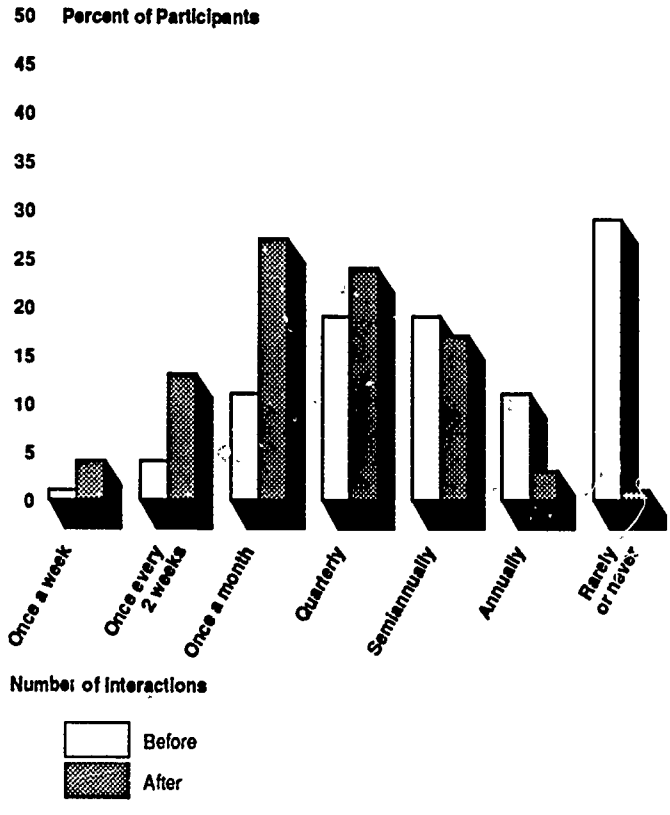
Company interaction with research personnel affiliated with the center has increased since companies have joined the ERC. (See fig. III.8.) A comparison of contacts with center personnel before and after joining the center showed the following:

- Of 32 reporting quarterly contacts before the center was established, 16 reported once-a-month and 7 reported once-every-2-weeks contact after the center was established.
- Of 32 reporting semiannual contacts before the center was established, 10 reported quarterly and 10 reported once-a-month contact after the center was established.
- Of 18 reporting annual contact before the center was established, 4 reported semiannually and 11 reported quarterly or more often contact after the center was established.

- Of the 48 reporting rare or no contacts before the center was established, 16 reported semiannual contacts, 16 reported quarterly contacts, and 10 reported once-a-month contacts after the center was established.

Although the numbers showed increased interaction, some participants commented on the need for better interaction. One participant commented that he would like to stimulate more "one on one" interaction between company research scientists/engineers and the ERC student/faculty. He said that this activity must be motivated by individuals in both parties and be based on mutual work interests. Another participant stated that broader and more substantive industry involvement would be desirable.

Figure III.8: Industry Sponsor Interaction With ERC Personnel Before and After ERC Establishment



Limited Collaborative Research

Although participants reported many interactions with the ERC, they reported a limited number of specific collaborative efforts on research projects either at the ERC or at the participants' laboratories.

- Of 161 participants, 45, or 27 percent, reported that at least one company researcher collaborated with ERC faculty or students on-site at the ERC. Twenty-six reported 2 researchers who collaborated with ERC faculty or students, 14 reported 3 researchers, and 7 reported 4 researchers. Days that they spent on-site at the ERC ranged from 1 to 100.
- Of the 161 participants, 39, or 23 percent, reported that ERC faculty or students had collaborated with the company researchers at the company labs. Twenty-five reported that at least one ERC researcher spent 1 or more days (range was from 1 to 60 days). Twenty-one reported at least one ERC student spent 1 or more days at the company labs (range was from 1 to 90 days).

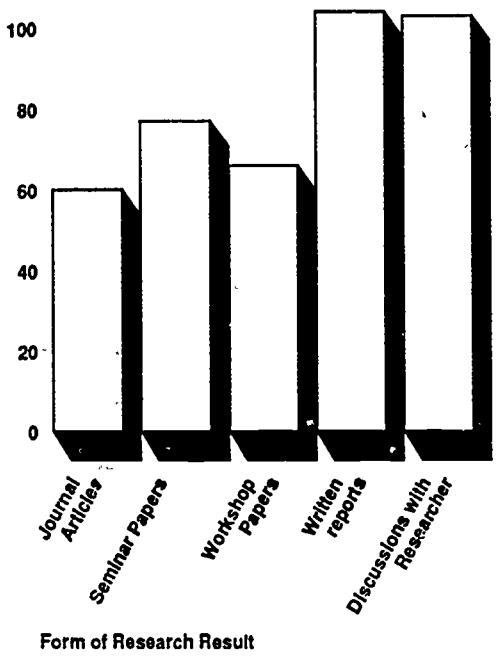
One participant commented that he would like to see ERC researchers spend more time at company facilities.

Although direct collaboration on research projects is limited, 88 participants reported observing research in progress one or more times in the past year (range was from 1 to 50 times). In addition, 125 reported attending seminars and/or workshops as observers one or more times in the past year (range was from 1 to 50 times), 78 reported attending seminars/workshops as participants one or more times (range was from 1 to 50 times), and 84 reported participating on the ERC advisory board one or more times (range was from 1 to 6 times).

Communication of Research Results

A majority of participants (about 80 percent) reported receiving some results of research performed at the ERC. Participants cited written progress or technical research reports (78 percent) as the most frequent forms of communicating research results. The next most often cited forms were discussions with the researcher (77 percent) and seminar papers (58 percent). (See fig. III.9.)

Figure III.9: Research Results Received by Participants



Note: Respondents could check more than one response.

We also examined this question with respect to the age of the center to determine whether any differences occurred over time. About 85 percent of the participants associated with 1985 centers and about 83 percent of the participants associated with 1986 centers said they had received some results of research. Table III.2 shows the type and percentage of research results received.

Table III.2: Results of Research Received by Year ERC Was Established

Figures in Percent

Result of research received	Associated with 1985 ERC	Associated with 1986 ERC
Written progress or technical research reports	76	82
Discussions with researcher	76	77
Seminar papers	63	48
Workshop papers	48	50
Journal articles	45	46

Indications of Technology Transfer

Indications of technology transfer may include (1) whether participants had continued ERC research projects at their own labs and (2) whether the ERC research had spawned new research projects for the company. In response to the first question, about 55 percent of the participants reported that they had never continued research at their own laboratories but may in the future, and 13 percent reported that it was too early to determine whether they would continue research at their laboratories. In response to the second question, about 39 percent of the participants reported that research conducted at the ERC had never spawned new research projects for the company, and 32 percent reported that it was too early to tell.

We also looked at the responses on the basis of when the center was established to see whether any differences occurred over time. We found the following:

- Of 104 participants associated with 1985 ERCs, 19, or 18 percent, reported that they had continued research projects started at the ERC back at their own laboratories at least one time. Of 51 participants associated with 1986 ERCs, 9, or 18 percent, reported that they had continued research projects started at the ERC back at their own laboratories at least one time.
- Overall, of 103 participants associated with 1985 ERCs, 27, or 26 percent, reported that research conducted at the ERC had spawned new research projects for the company at least once, and 29, or 28 percent, reported that it was too early to tell. Of the 52 participants associated with 1986 ERCs, 10, or 19 percent, reported that research at ERCs had spawned new research projects for the company one or more times, and 24, or 46 percent reported that it was too early to tell.

Technology transfer was another aspect of the ERC program that participants wanted to see strengthened or changed. One participant wanted a technology transfer infrastructure and another wanted more enlightenment on how technology transfer actually can result in competitive products and ideas.

Expected Tangible Benefits of ERC Participation

We also asked whether participants expected any tangible benefits from the ERC in the next 5 to 7 years. Table III.3 shows participants' expectations.

Table III.3: Benefits Expected by Participants in 5 to 7 Years

Figures in Percent

Expected benefit	Yes	No	Too early to tell
Better personnel recruitment	74	9	12
Improvement of current personnel	83	7	8
Improved company research projects	67	15	13
Patentable products	11	68	16
Commercial products	25	51	17

We also asked center directors how much benefit they expected sponsoring companies to realize from participation in the ERC. Of the 13 center directors, on a scale of very great benefit to little or no benefit,

- 10 expected participants would receive a great to very great benefit in better personnel recruiting,
- 7 expected participants would receive a great to very great benefit through improvement of current personnel, and
- 9 expected participants would receive a great to very great benefit through improved research projects.

A majority of center directors believed that participants would receive a moderate or great benefit through patentable products and commercialized products, although industry participants were not nearly as optimistic.

Industry Profile

Many types of companies are participating in the ERCs, from heavy industry to newer companies in high technology areas. (App. VIII lists the research areas as reported by the industry respondents.) About 28 percent of the participants reported gross sales for 1986 under $1 billion, 29 percent reported gross sales between $1 billion and $5 billion, and 29 percent reported gross sales over $5 billion. The ERCs reported that 50 small businesses (500 or fewer employees) participated in their centers in fiscal year 1987. The MIT Biotechnology Process Engineering Center reported 23 small businesses for 1987, almost half of those reported. Eleven ERCs reported that they have special programs to encourage or enable small businesses to participate in the ERC. We received a few comments on this aspect of the ERC program, including

- ERCs should make more effort to get involved with small and medium-size industrial sponsors,
- small companies should be treated the same as large companies, and

- ERCs should be made more attractive to small companies.

Generally, participants reported spending most of their research budgets for internal research. Only 5 percent of the participants reported that over 50 percent of their current research budget was for external research and development. About 78 percent reported spending 10 percent or less of their research budget on external research and development. Of the 9 participants reporting over 50 percent of their research budget was for external research and development, 3 reported spending between 5 and 50 percent on research at universities and 4 reported spending over 50 percent on research at universities.

Participants tend to spread out their external research and development budgets over several types of performers. About 7 percent of the participants reported spending over 50 percent of their external research budget on research at ERCs and about 68 percent reported spending 10 percent or less. (See fig. III.10.) In addition, participants reported spending external research funds for individual university researchers other than those at the ERC (about 70 percent), for research at institutions other than universities (about 48 percent), for consultants or consulting firms (about 60 percent), and for other private industry (about 33 percent).

A majority of participants in ERCs have been sponsoring research at universities for many years. About 55 percent of the respondents reported sponsoring research at universities for 10 or more years, while about 29 percent of the respondents reported sponsoring research at universities for less than 4 years. (See fig. III.11.) In looking at the responses by center affiliation, about 67 percent of the 98 participants associated with 1985 ERCs and about 66 percent of the 50 participants associated with 1986 ERCs reported sponsoring research at universities for over 5 years.

Of 160 industrial respondents, 142 reported that their company's corporate headquarters is located in the United States.

Figure III.10: Percentage of Industry External Research Budget to ERCs

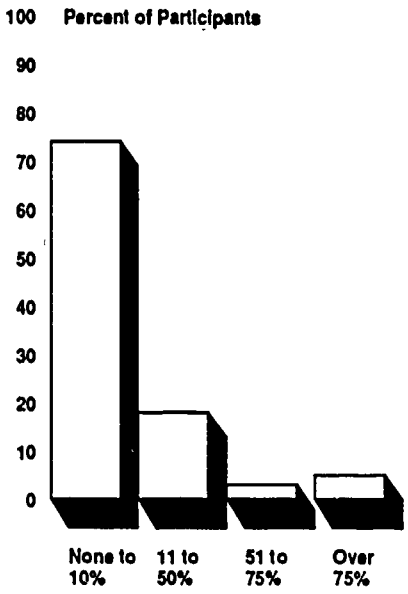
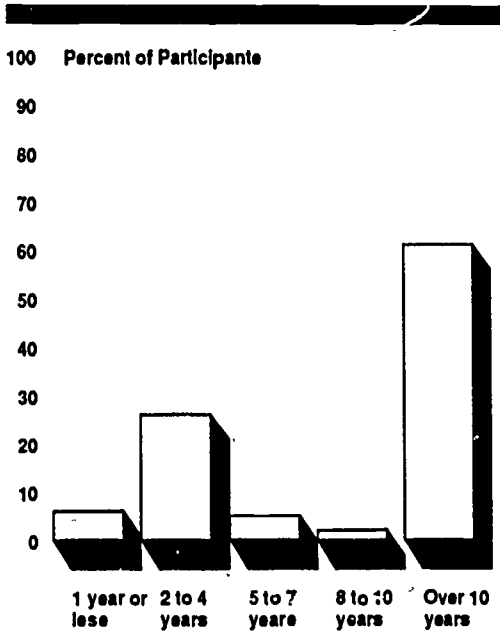


Figure III.11: Number of Years Industry Respondents Have Sponsored University Research



Conclusions

Although NSF's Engineering Research Center program is only 3 years old, it has been well received by industry. Participants intend to continue sponsoring the ERCs, and the centers reported that most companies were able to keep their financial commitment.

A majority of the participants believed that quality and type of research were the most important reasons for sponsoring ERCs. Although joint and cross-disciplinary research are intended characteristics of the ERC program, industry sponsors rated these as only very to moderately important reasons for sponsoring ERCs. Interaction between university and industry research personnel has increased since the establishment of the ERC, although direct collaboration on research projects is limited. Participants expected to receive the most benefit from their participation through improvement of their current personnel, better personnel recruitment, and improved research projects. Because the ERC program is relatively new, participants have not hired many ERC students, and therefore it is too early to determine the program's impact on engineering education. In addition, it is too early to tell what impact the ERC program will have on technology transfer.

A significant concern participants raised is their influence on the ERC's research agenda. A majority of the participants reported some to little or no influence on the ERC research agenda. Many also commented that this aspect should be strengthened or changed.

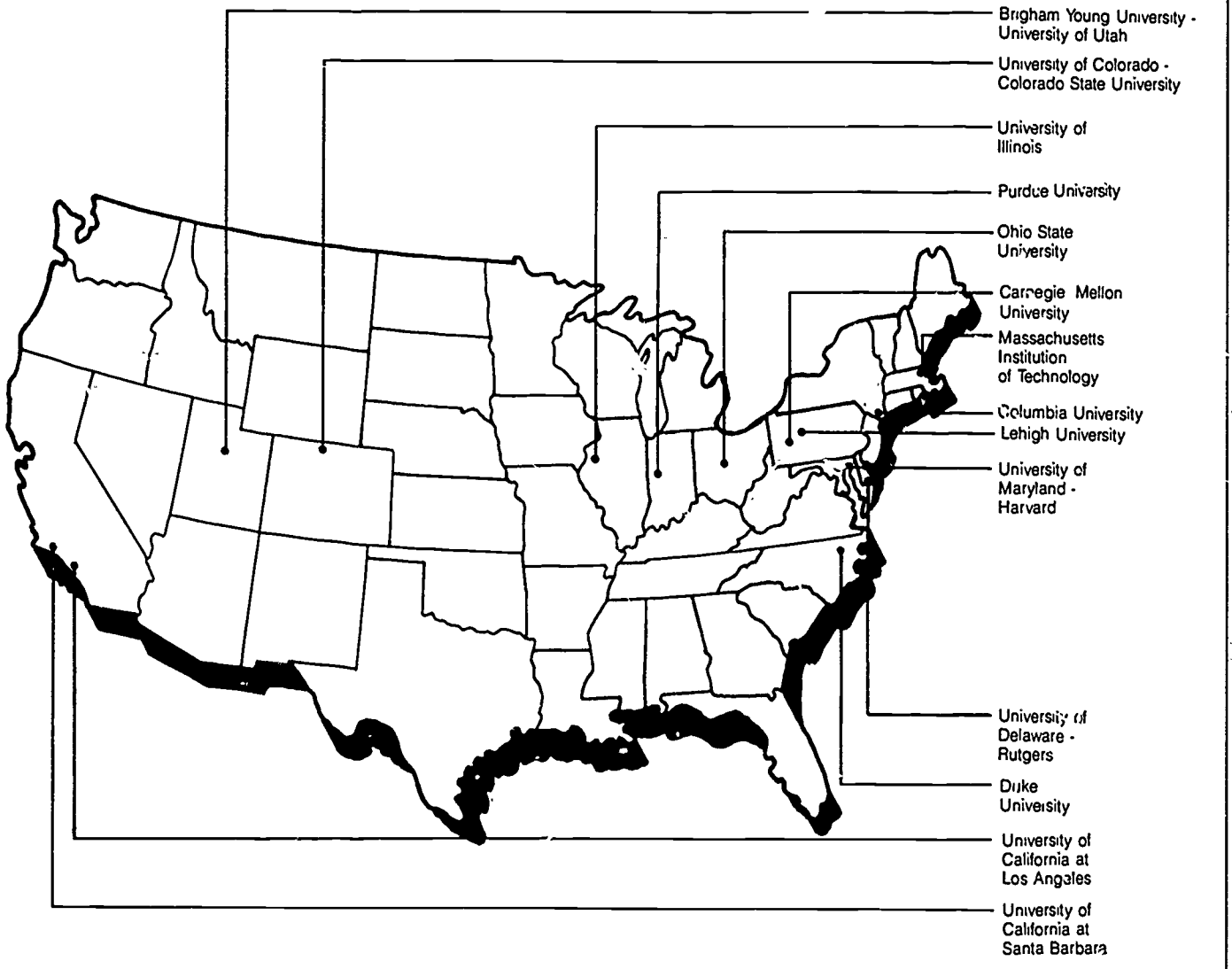
Subject Areas of the National Science Foundation-Supported Engineering Research Centers

1985 Awards	University of California, Santa Barbara: Robotics for Microelectronics
	Massachusetts Institute of Technology: Bioprocess Engineering
	Purdue University: Intelligent Manufacturing Systems
	Columbia University: Telecommunications
	University of Delaware/Rutgers:* Composites for Manufacturing
	University of Maryland/Harvard University:* Systems Engineering
1986 Awards	Ohio State University: Near Net-Shape Manufacturing
	Carnegie-Mellon University: Design Engineering
	Brigham Young University/University of Utah:* Combustion Research
	University of Illinois: Microelectronics
	Lehigh University: Construction of Large Structures
1987 Awards	University of Colorado/Colorado State University:* Optoelectronics
	University of California, Los Angeles: Hazardous Waste Management
	Duke University: Cardiac Technology

Source: NSF.

*Joint ERC.

Location of Engineering Research Centers, 1985 to 1987



Source: NSF.

GAO Survey of Industrial Participants in the National Science Foundation's Engineering Research Centers

U.S. GENERAL ACCOUNTING OFFICE
SURVEY OF INDUSTRIAL PARTICIPANTS IN
THE NATIONAL SCIENCE FOUNDATION'S
ENGINEERING RESEARCH CENTERS

The U.S. General Accounting Office (GAO), an agency responsible for evaluating federal programs, is examining the National Science Foundation's (NSF's) Engineering Research Center (ERC) program. GAO has been requested by the Senate Committee on Commerce, Science, and Transportation to assess selected aspects of NSF's ERC program, particularly industry's role in the ERC program. ERC program objectives include developing fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry and preparing engineers to contribute through better engineering practices.

The Committee specifically requested that we survey selected American companies to learn their reaction to the ERC program. To help us fulfill the Committee's request, we would appreciate your answering this questionnaire. According to NSF, key ingredients of the ERC program are strong industrial participation and timely knowledge transfer. We want to learn whether these key ingredients are in fact part of the ERC program. This information will assist the Committee in its decision-making role on the ERCs.

To fulfill the request we are surveying all companies that the ERCs have reported to us as participating in their centers. Please help us by completing this questionnaire and returning it within ten days of receipt, if possible. It should take no more than 20 to 30 minutes to complete. When you have completed this questionnaire, please return it in the enclosed self-addressed business reply envelope. If the envelope has been misplaced please mail the completed questionnaire to:

Ms. Ilene Pollack
Room 4476
U.S. General Accounting Office
441 G Street, N.W.
Washington, D.C. 20548

If you have any questions about the questionnaire please call Ilene Pollack at (202) 634-4929.

Thank you for your help.

Note: Over the course of this questionnaire we have used the term "company unit". By this we mean the division, center, group, department, or other designated organization that your answers represent.

Please state the company unit, that is, the division, center, group, department, or other designated organization, your answers represent.

ID (1-3)
CD1(4)

_____

SECTION 1

In this section, we are interested in determining what motivates a company to participate in NSF's Engineering Research Centers (ERCs).

1. How important, if at all, were the following reasons for your company unit participating in the ERC? (Check one for each reason) (5-14)

n=168

	Extremely Important 1.	Very Important 2.	Moderately Important 3.	Somewhat Important 4.	Not at all Important 5.
1. Research at center matches our interests	53%	35.7%	5.4%	1.8%	.6%
2. Center is doing state-of-the-art research that interests us	47.6%	40.5%	5.4%	3.0%	--
3. Access to students trained at ERC	13.7%	28.6%	35.1%	14.9%	3.6%
4. Access to state-of-the-art equipment that our unit does not have	4.2%	10.7%	32.7%	26.2%	22.6%
5. Opportunity for joint research	9.5%	34.5%	28.6%	19.0%	4.2%
6. Opportunity for cross-disciplinary research	15.5%	31.0%	27.4%	15.5%	6.0%
7. Quality of knowledge and/or researchers at ERC	38.7%	49.4%	6.5%	1.8%	--
8. Access to results of ERC research	27.4%	45.2%	19.0%	4.9%	--
9. Opportunity to interact with companies affiliated with the ERC	11.3%	24.4%	25.0%	25.6%	8.9%
10. Opportunity to develop new research project	14.9%	29.2%	27.4%	19.0%	5.4%

1. (contd.) How important, if at all, were the following reasons for your company unit participating in the ERC? (Check one for each reason.) (15-20) n=168

	Extremely Important 1.	Very Important 2.	Moderately Important 3.	Somewhat Important 4.	Not at all Important 5.
11. Opportunity to develop patentable products	2.4%	6.0%	15.5%	29.2%	43.5%
12. Proximity of ERC to company	6.0%	13.1%	22.6%	20.2%	33.9%
13. Access to up-to-date information in field research of ERC	22.6%	48.2%	18.5%	5.4%	1.2%
14. Access to technical assistance from ERC personnel	13.1%	31.5%	33.3%	14.9%	15.4%
15. Ability to multiply research investment with money from other ERC participants	20.2%	28.0%	27.4%	13.7%	7.1%
16. Other, please specify					

2. In your opinion, will your company unit support the ERC in each of the following years? (Check one for each year) (21-24)

	Definitely yes 1.	Probably yes 2.	Uncertain 3.	Probably no 4.	Definitely no 5.
1. One year from now	56.5%	28.6%	3.0%	--	1.8%
2. Two years from now	26.8%	50.0%	12.5%	1.2%	1.2%
3. Three years from now	10.7%	47.6%	32.7%	1.2%	1.2%
4. Four years or more from now	9.5%	31.0%	50.6%	1.2%	1.2%

n=168

If you answered "Probably yes" or "Definitely yes" for any of the years please answer question 3; if not, please skip to question 4.

3. Compared to your present level of financial and personnel support, at what general level do you expect your company unit to continue its support of the ERC? (Check one)

(25)

.7% 1. [ ] Much higher than the current year

11.6% 2. [ ] Somewhat higher than the current year

84.4% 3. [ ] About the same as the current year n=146

2.7% 4. [ ] Somewhat lower than the current year

0 5. [ ] Much lower than the current year

4. One program goal of the ERCs is to stimulate cross-disciplinary research. In your opinion, has the ERC done research that you would consider cross disciplinary? (Check one)

(26)

8.3% 1. [ ] No -----> SKIP TO 6

n=168

85.1% 2. [ ] Yes

5. How much benefit, if any, has cross-disciplinary research at the ERC had for your company unit? (Check one)

(27)

9.8% 1. [ ] Little or no benefit

37.8% 2. [ ] Some benefit n=143

31.5% 3. [ ] Moderate benefit

17.5% 4. [ ] Great benefit

1.4% 5. [ ] Very great benefit

6. Another program goal of ERCs is to strengthen both undergraduate and graduate engineering education. Since your participation in the ERC began, have you or your company unit hired any students that have graduated from the ERC? (Check one)

(28)

19.6% 1. [ ] Yes

n=168

76.2% 2. [ ] No -----> SKIP TO 9

7. How many of these students have you hired? (If none for a category enter "0" for that category)

(29-34)

38 Number of undergraduate students

n=33

36 Number of graduate students

8. In your opinion, how much better or worse is the preparation of ERC students compared to students from traditional (i.e., non-ERC engineering programs) in each of the following skill areas? (Check one for each skill area.)

(35-39)

	Much better 1.	Somewhat better 2.	Neither better nor worse 3.	Somewhat worse 4.	Much worse 5.	n=33
1. Knowledge of state of the art equipment	27.3%	57.6%	15.2%			
2. Knowledge of areas in which company is specifically interested	39.4%	48.5%	12.1%			
3. Capability for thinking on a systems basis	30.3%	30.3%	36.4%			
4. Ability to work in your company's environment	36.4%	42.4%	21.2%			
5. Other (please specify)						

SECTION 2

In this section, we want to determine how companies interact with ERCs.

9. How did you or your company unit find out about the ERC? (Check all that apply.)

(40-46)

n=168

65.5% 1. [ ] I had previous knowledge of faculty at the university

61.9% 2. [ ] I had previous knowledge of research at the university

56.5% 3. [ ] Others in my company unit had previous knowledge of faculty or research at the university

45.2% 4. [ ] I or others in my company unit had a prior relationship with the center's research director before center was established

14.3% 5. [ ] I or others in my company unit were approached by center staff members without previously-knowing them

9.5% 6. [ ] I or others in my company unit heard about it at an annual industry meeting

9.5% 7. [ ] Other (please specify)

10. Is your company unit a member of any other NSF sponsored ERC? (Check one)

73.8% 1. [ ] No n=168 (47)

19.0% 2. [ ] Yes -----> Please list _____

11. Have you or others in your company unit been approached to join any of the other ERCs? (Check one)

(48)

59.5% 1. [ ] No n=168

29.2% 2. [ ] Yes -----> Please list _____

12. Prior to your company unit's participation in the ERC, how frequently, if ever, did you or your company unit's research management typically have contact with research personnel now affiliated with the ERC? (Check one)

1.2% 1. [ ] More than once a week (49)

1.2% 2. [ ] Once a week

3.6% 3. [ ] Once every two weeks

10.7% 4. [ ] Once a month n=168

19.0% 5. [ ] Quarterly

19.0% 6. [ ] Semiannually

11.3% 7. [ ] Annually

28.6% 8. [ ] Rarely or never

13. Since your company unit first began its participation with the ERC, how frequently, if ever, do you or your company unit's research management typically have contact with ERC research personnel? (Check one)

4.8% 1. [ ] More than once a week (50)

3.6% 2. [ ] Once a week

13.1% 3. [ ] Once every two weeks

27.4% 4. [ ] Once a month n=168

23.8% 5. [ ] Quarterly

17.3% 6. [ ] Semiannually

3.0% 7. [ ] Annually

1.2% 8. [ ] Rarely or never

14. Prior to your company unit's affiliation with the ERC, did you or your company unit interact with university personnel now associated with the ERC? (Check one)

(51)

64.3% 1. [ ] Yes

n=168

32.1% 2. [ ] No -----> SKIP TO 16

15. Since becoming affiliated with the ERC, has your company's use of the following types of research support or interaction increased, decreased, or stayed the same? (Check one for each activity.) (52-58)

	Great increase 1.	Some increase 2.	No change 3.	Some decrease 4.	Great decrease 5.
1. Use of faculty as consultants	3.7%	33.3%	53.7%	2.8%	--
2. Contracts for research projects	2.8%	23.1%	63.9%	3.7%	.9%
3. General support of faculty research	4.6%	27.8%	57.4%	3.7%	--
4. Support of student thesis research	2.8%	20.4%	66.7%	1.9%	--
5. Providing company unit personnel as adjunct faculty	4.6%	13.0%	74.1%	.9%	
6. Graduate or undergraduate students working at company unit	2.8%	25.0%	65.7%	.9%	--
7. Other, please specify					

n=108

16. How many of your company unit's employees of the following types, if any, have interacted with the ERC in the past year? (If none, enter "0")

	Number of employees
1. Company researchers	655
2. Research project managers	313
3. Sales managers	39
4. Research directors or vice-presidents	242
5. Technical or operating engineers	340
6. Other, please specify	17

(59-76)

n=168

17. In the past year, have any of your company unit's researchers collaborated with the ERC's faculty or students on research projects on-site at the ERC? (Check one)

(77)

26.8% 1. [ ] Yes

n=168

69.0% 2. [ ] No -----> SKIP TO 19

18. For the researchers from your company unit that have spent time working on-site at the ERC, approximately how many days were spent at the ERC in the past year? (If none, enter "0")

	Approximate number of days at ERC in past year	(78-89)
1. Researcher 1	1-100	
2. Researcher 2	1-80	n=45
3. Researcher 3	1-30	
4. Researcher 4	1-30	

If room for more researchers is necessary please continue on separate sheet.

19. In the past year, have any of the ERC researchers or students collaborated with your company researchers on research projects at your laboratories? (Check one)

(90)

24.2% 1. [ ] Yes

n=168

2. [ ] No -----> SKIP TO 21

20. For the ERC researchers or students that have spent time working on-site at your laboratories, approximately how many days did they spend at your laboratories in the past year? (If none, enter "0")

	Approximate number of days at your laboratories in the past year	ID (1-3) CD2(4) (5-16)
1. Researcher 1	1-60	
2. Researcher 2	1-26	n=39
3. Student 1	1-90	
4. Student 2	1-60	

If room for more researchers or students is necessary please continue on separate sheet.

21. In the past year, how many times, if any, have you or personnel from your company unit had the following types of interactions with the ERC? (If none, enter "0")

(17-31)

	Number of times interaction has occurred RANGE	n=168 NO. REPORTING
1. Observe research in progress	1-50	88
2. Attend seminars and/or workshops as observer	1-50	124
3. Attend seminars and/or workshops as participant	1-50	78
4. Participate in the ERC advisory board	1-6	84
5. Other, please specify		

22. In your opinion, how much influence, if any, do you have on the ERC's research agenda? (Check one)

(32)

15.5%	1.	[ ]	Little or no influence
42.3%	2.	[ ]	Some influence
25.0%	3.	[ ]	Moderate influence
11.3%	4.	[ ]	Great influence
1.8%	5.	[ ]	Very great influence

n=168

23. What types of information, if any, do you receive from the center? (Check all that apply.)

(33-38)

85.1%	1.	[ ]	Newsletters on ERC activities and research
78.6%	2.	[ ]	Progress or technical reports on research
58.3%	3.	[ ]	Seminar papers
42.9%	4.	[ ]	Workshop papers
17.9%	5.	[ ]	Other (please specify)
	6.	[ ]	None

n=168

24. Are there aspects of the ERC's programs that you would like to see changed or strengthened? (Check one)

(39)

44.0% 1. [ ] No

n=168

47.0% 2. [ ] Yes -----> What aspects would you like to change?

SECTION 3

In this section, we are interested in examining how technology is transferred from the ERC to the industries involved with them.

25. Have you or your company unit received any results of research performed at the ERC? (Check one)

(40)

79.8% 1. [ ] Yes

n=168

16.1% 2. [ ] No -----> SKIP TO 27

26. In which of the following forms have you or your company unit received the results of research performed at the ERC? (Check all that apply)

44.8% 1. [ ] Journal articles (41-47)

57.5% 2. [ ] Seminar papers

49.3% 3. [ ] Workshop papers

77.6% 4. [ ] Written progress or technical research reports n=134

76.9% 5. [ ] Discussions with researcher

56.0% 6. [ ] Discussions with research director

20.9% 7. [ ] Other (Please specify)

27. About how many times, if ever, has your company continued research projects at your own labs that were started at the ERC? (Check one)

(48)

9.5%	1. [ ]	Never, and have no such intention for the future	
55.4%	2. [ ]	Never, but may in the future	
16.1%	3. [ ]	1 to 3 times	
.6%	4. [ ]	4 to 6 times	n=168
	5. [ ]	7 to 9 times	
	6. [ ]	10 or more times	
12.5%	7. [ ]	Too early to know	

28. About how often, if ever, has the research conducted at the ERC spawned new research projects for your company? (Check one)

(49)

39.3%	1. [ ]	Never	
21.4%	2. [ ]	1 to 3 times	
1.2%	3. [ ]	4 to 6 times	n=168
	4. [ ]	7 to 9 times	
	5. [ ]	10 or more times	
32.1%	6. [ ]	Too early to know	

29. As a result of your participation in the ERC, to what extent, if at all, do you or others from your company unit interact with other companies involved with the ERC? (Check one)

(50)

44.0%	1. [ ]	Little or no extent	
32.1%	2. [ ]	Some extent	
16.7%	3. [ ]	Moderate extent	n=168
1.8%	4. [ ]	Great extent	
.6%	5. [ ]	Very great extent	

30. In your opinion, will your company unit realize tangible benefits over the next 5 to 7 years in the following areas as a result of your participation in the ERC? (Check one for each benefit.)

(51-56)

	Definitely yes	Probably yes	Probably no	Definitely no	Too early to tell	n=168
	1.	2.	3.	4.	5.	
1. Better personnel recruitment	20.8%	53.0%	7.1%	1.8%	11.9%	
2. Improvement of current personnel through interaction with ERC	27.4%	55.4%	7.1%	--	7.7%	
3. Improved research projects with the company	14.9%	51.8%	13.7%	1.2%	12.5%	
4. Patentable products	.6%	10.1%	54.2%	13.7%	15.5%	
5. Commercialized products	3.6%	81.4%	37.5%	13.7%	17.3%	
6. Other (please specify)						

SECTION 4

To understand what types of industries are participating in ERCs, we would appreciate some background information on your company.

31. What is the major output of your company unit? (If the main function of your unit is research, please state, in general terms, what the research is working toward.)

(57)

94.6% n=168

32. About what percentage of your company unit's current research budget goes to external research and development? (Check one)

(58)

1.8%	1. [ ]	None	
50.0%	2. [ ]	Less than 5 percent	
23.2%	3. [ ]	5 to 10 percent	
5.4%	4. [ ]	11 to 25 percent	n=168
3.6%	5. [ ]	26 to 50 percent	
1.2%	6. [ ]	51 to 75 percent	
4.2%	7. [ ]	Over 75 percent	

33. Of the amount spent on external research, about what percentage is currently spent on research at universities? (Check one)

(59)

5.4%	1. [ ]	None	
22.6%	2. [ ]	Less than 5 percent	
10.1%	3. [ ]	5 to 10 percent	
8.3%	4. [ ]	11 to 25 percent	n=168
5.4%	5. [ ]	26 to 50 percent	
10.7%	6. [ ]	51 to 75 percent	
26.8%	7. [ ]	Over 75 percent	

34. About what percentage, if any, of your company unit's external research is performed by the following individuals or groups other than the ERC? (Check the approximate percentage for each group.) (60-64)

	None	0% to 20%	21% to 40%	41% to 60%	61% to 80%	81% to 100%
	1.	2.	3.	4.	5.	6.
1. Individual university researchers	11.9	28.0	8.3	8.9	13.7	11.3
2. Research institutions other than universities	19.0	34.5	7.1	3.0	2.4	.6
3. Consultants and/or consulting firms	13.7	42.3	12.5	2.4	1.8	.6
4. Other private industry	24.4	20.8	6.5	3.0	1.2	1.2
5. Other (please specify)						

n=168

35. Of the amount spent on external research, about what percentage is currently spent on research at the ERC? (Check one)

(65)

17.9%	1. [ ]	None	
38.1%	2. [ ]	Less than 5 percent	
11.9%	3. [ ]	5 to 10 percent	
11.3%	4. [ ]	11 to 25 percent	n=168
4.2%	5. [ ]	26 to 50 percent	
3.0%	6. [ ]	51 to 75 percent	
4.2%	7. [ ]	Over 75 percent	

36. How long has your company unit sponsored research at universities? (Check one)

(66)

5.4%	1. [ ]	1 year or less	
23.8%	2. [ ]	2 to 4 years	
4.2%	3. [ ]	5 to 7 years	
1.8%	4. [ ]	8 to 10 years	n=168
54.8%	5. [ ]	Over 10 years	

37. What is the approximate cost of your company unit's participation in the ERC for the past year?

(67-90)

	Approximate cost	
Yearly fee	$ 1,000 to 525,000	
Staff	$ 1,000 to 300,000	n=168
Equipment use and/or donation	$ 2,000 to 350,000	
Any other contributions (please specify)	$ 2,000 to 350,000	ID (1-3) CD3(4)

38. What was your company's, that is your company unit's corporate parent and all its affiliates, gross sales for 1986?

(5-13)

$ 3,000 to 102 billion n=168

39. Is your company's, that is your company unit's corporate parent and all its affiliates, corporate headquarters located in the United States?
(14)

84.5% 1. [ ] Yes

10.7% 2. [ ] No n=168

40. If you have any further comments on any of the subjects discussed in this questionnaire please add them here.
(15)

GAO Survey of the National Science Foundation's Engineering Research Centers

U.S. GENERAL ACCOUNTING OFFICE
SURVEY OF NATIONAL SCIENCE FOUNDATION
ENGINEERING RESEARCH CENTERS

The U.S. General Accounting Office (GAO), an agency responsible for evaluating federal programs, is examining the National Science Foundation's (NSF's) Engineering Research Center (ERC) program. GAO has been requested by the Senate Committee on Commerce, Science, and Transportation to assess selected aspects of NSF's ERC program, particularly industry's role in the ERC program. ERC program objectives include developing fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry and preparing engineers to contribute through better engineering practices.

To help fulfill the request we are surveying all centers. According to NSF, key ingredients of the ERC program are strong industrial participation and timely knowledge transfer. We want to learn whether these key ingredients are in fact part of the ERC program. This information will assist the Committee in its decision-making role on the ERCs.

For questions asking information by year, if the center had not yet been established, please write "not applicable" in the space provided. Because we would like to keep our data as consistent as possible we are using the federal fiscal year which runs from October 1 until September 30. (For example, "1985" is fiscal year 1985 which started October 1, 1984, and ended September 30, 1985.) We understand that your center may not use this year for accounting purposes so you may need to pro rate the information requested. Also, dollar figures can be approximate.

Please help us by completing this questionnaire within ten days of receipt, if possible. It should take no more than 30 to 40 minutes to complete. Please return the questionnaire in the enclosed self-addressed business reply envelope. If the envelope has been misplaced please mail the completed questionnaire to:

Ms. Ilene Pollack
Room 4476
U.S. General Accounting Office
441 G Street, N.W.
Washington, D.C. 20548

If you have any questions about the questionnaire, please call Ilene Pollack at (202) 634-4929.

Thank you for your help.

1. In the past twelve months, how many times, if ever, has your center carried out the following activities?

ID (1-2)
CD1(3)
(4-13)

	Never 1.	1-5 times 2.	6-10 times 3.	11-15 times 4.	16 or more times 5.	
1. Held events such as technical seminars, workshops, and symposia that industry sponsors attended		23.1%	30.8%	7.7%	38.5%	n=13
2. Held events such as technical seminars, workshops, or symposia that industry sponsors helped present	7.7%	76.9%	7.7%	7.7%		n=13
3. Initiated joint research with industry sponsors at the center		46.2%	23.1%	15.4%	15.4%	n=13
4. Held advisory panel or committee meetings for industry sponsors		84.6%		15.4%		n=13
5. Provided to industry sponsors software created at the ERC and/or from the ERC software library	23.1%	53.8%	7.7%		7.7%	n=12
6. Provided information to industrial sponsors on students studying at the ERC		30.8%	30.8%	7.7%	30.8%	n=13
7. Issued newsletters on center activities to industrial sponsors	7.7%	76.9%	15.4%			n=13
8. Issued technical reports on results of research sponsored by industry	7.7%	38.5%	15.4%	7.7%	30.8%	n=13
9. Have people from industry lead educational programs (such as courses or seminars)	15.4%	38.5%	23.1%	15.4%	7.7%	n=13
10. Other (please list)						

2. To what extent, if at all, do you use each of the following mechanisms to identify the companies to be targeted for participation in the ERC? (Check one for each mechanism) (14-18)

	Little or no extent 1.	Some extent 2.	Moderate extent 3.	Great extent 4.	Very great extent 5.	
1. Previous faculty contacts with companies		23.1%	23.1%	30.8%	23.1%	n=13
2. Previous contacts with companies through other university research programs		46.2%	23.1%	23.1%	7.7%	n=13
3. Companies' historical relationship and support of the university in the past		30.8%	30.8%	23.1%	15.4%	n=13
4. Company contacted the ERC on its own initiative		23.1%	15.4%	53.8%	7.7%	n=13
5. Other (please specify)						

3. For each fiscal year, how many, if any, individual companies participated in your center? (If center not established enter "N/A"; if established but no participants enter "0") (19-26)

1. FY 1985 217
2. FY 1986 267
3. FY 1987 301
4. FY 1988 420 -----> [8] Please check here if you had to estimate number of companies for FY 1988. (27)

4. During each fiscal year of the center's operation, how many of each of the following types of personnel from the companies that sponsor (affiliate with) the center spent at least one day at the center? (Enter number; if not in operation during a fiscal year, enter "N/A")

	FY 1985	FY 1986	FY 1987	
1. Company researchers	99	241	517	(28-39)
2. Research managers	48	95	205	(40-51)
3. Sales managers	12	36	43	(52-63)
4. Others (please specify)	22	53	82	(64-75)

5. For each of the following fiscal years, how much influence, if any, did industry have on your research agenda? (Check one for each fiscal year)

(76-79)

	Little or no influence 1.	Some influence 2.	Moderate influence 3.	Great influence 4.	Very great influence 5.	
1. FY 1985		67%	33%			n=6
2. FY 1986	9%	9%	64%	18%		n=11
3. FY 1987			46%	46%	8%	n=13
4. FY 1988			23%	69%	8%	n=13

6. Through what means, if any, did industry influence the center's research agenda?

(80)

7. In your opinion, how important, if at all, are the following factors in attracting industrial sponsors to the center? (Check one for each factor)
(81-91)

	Extremely Important 1.	Very Important 2.	Moderately Important 3.	Somewhat Important 4.	Not at all Important 5.	
1. Research at center matches sponsor interests	69.2%	30.8%				n=13
2. Center is doing state-of-the-art research that sponsors are interested in	61.5%	30.8%	7.7%			n=13
3. Access to students trained at ERC	23.1%	53.8%	15.4%	7.7%		n=13
4. Access to state-of-the-art equipment at the center		15.4%	30.8%	38.5%	15.4%	n=13
5. Opportunity for joint research	7.7%	46.2%	23.1%	23.1%		n=13
6. Opportunity for cross-disciplinary research		46.2%	46.2%	7.7%		n=13
7. Quality of knowledge and/or researchers at ERC	61.5%	38.5%				n=13
8. Access to results of ERC research	38.7%	53.8%	7.7%			n=13
9. Opportunity to interact with companies affiliated with ERC	7.7%	15.4%	38.5%	38.5%		n=13
10. Opportunity to develop new research projects	15.4%	53.8%	15 4%	15.4%		n=13
11. Opportunity to develop patentable products	15.4%	7.7%	23.1%	38.5%	15.4%	n=13

7. (contd.) In your opinion, how important, if at all, are the following factors in attracting industrial sponsors for the center? (Check one for each factor) (92-96) ID (1-2) CD2(3)

	Extremely Important 1.	Very Important 2.	Moderately Important 3.	Somewhat Important 4.	Not at all Important 5.	
12. Proximity of ERC to company		23.1%	46.2%	23.1%	7.7%	n=13
13. Access to up-to-date information in field of research at ERC	15.4%	53.8%	30.8%			n=13
14. Access to technical assistance from ERC personnel	23.1%	38.5%	38.5			n=13
15. Ability to multiply research investment money from other ERC participants.	15.4%	53.8%	15.4%	15.4%		n=13
16. Other (please specify)						

8. In your opinion, how much benefit, if any, will sponsoring companies realize in the following areas as a result of their participation in the ERC? (Check one for each area) (4-9)

	Very great benefit 1.	Great benefit 2.	Moderate benefit 3.	Some benefit 4.	Little or no benefit 5.	Too early to tell 6.	
1. Better personnel recruitment	23.1%	53.8%	15.4%	7.7%			n=13
2. Improvement of current personnel through interaction with ERC	7.7%	46.2%	38.5%	7.7%			n=13
3. Improved research projects with the company	15.4%	53.8%	23.1%	7.7%			n=13
4. Patentable products		23.1%	30.8%	7.7%	7.7%	30.8%	n=13
5. Commercialized products		30.8%	38.5%			30.8%	n=13
Other (please specify)							

9. Does the ERC establish a yearly goal for the amount of money it wants to receive from industry? (10)

1. [9] Yes

2. [4] No -----> SKIP TO 11

Please answer questions 10 through 14 for each fiscal year indicated.

	FY 1985	FY 1986	FY 1987	FY 1988	
10. What was your center's goal for the amount of money the center wanted to receive from industry for each fiscal year?	n=3 $.2mil to $1.1mil	n=6 $ .2mil to $1.5mil	n=8 $ .1mil to $2 mil	n=9 $ .3mil to $2.5mil	(11-34)
11. How much money, if any, did the ERC actually receive from industry in each fiscal year?	n=6 0 to $3.7mil	n=11 0 to $5 mil	n=13 $.1mil to $3.7mil		(35-58)

12. What was the approximate amount of support, if any, provided by industry for the following areas in each fiscal year? (If none enter "0")

	FY 1985	FY 1986	FY 1987	FY 1988	
1. Equipment (retail value in dollars)	n=5 0 to $.8mil	n=10 0 to $2.3mil	n=13 $.05 to $1.3mil	n=6 $.007to $1.5mil	(59-82) ID (1-2) CD3(3)
2. Personnel (FTEs)	data not comparable				(4-27)
3. Additional direct or indirect contributions (value in dollars)	n=2 $.05mil to $2.9mil	n=7 $.008 to $3.7mil	n=9 $.06mil to $1.9mil	n=6 $.06mil to $2.2mil	(28-51)

	FY 1985	FY 1986	FY 1987	FY 1988	
13. What percent, if any, of the ERC's total budget was comprised of industry dollar contributions in each fiscal year? (If none, enter "0")	n=6 0 to 66 %	n=11 0 to 39 %	n=13 3% to 44 %	n=6 6% to 55 %	(52-63)
14. What percent, if any, of the ERC's total budget was comprised of industry contributions (including equipment and personnel contributions) in each fiscal year? (If none, enter "0")	n=6 0 to 50 %	n=11 13% to 60 %	n=12 8% to 60 %	n=6 9% to 61 %	(64-75)

15. For any year the center has been in operation, has any company that made initial financial commitments to the ERC been unable to keep those commitments?

(76)

1. [9] No -----> SKIP TO 18

2. [4] Yes

16. For each fiscal year in which any companies were unable to keep initial financial commitments, please list the number of companies for which this occurred and the total amount of commitment not met. (Enter "0" if none.)

	Number of companies	Amount	
1. FY 1985	1	$ 20,000	(77-82)
2. FY 1986	4	$ 35,000	(83-88)
3. FY 1987	5	$138,000	(89-94) ID (1-2) CD4(3)

17. Why were the companies unable to keep these commitments? If you do not know, please check the box below.

1. [ ] Don't know (4)

2. Reasons (please list in order of importance): (5)

_____

_____

_____

_____

18. For each fiscal year, how many, if any, of your industry members were small businesses? (A small business is defined as an independently owned and operated business with 500 or less employees.) (If none, enter "0")

(6-11)

1. FY 1985 18

2. FY 1986 39

3. FY 1987 50

19. Does your center have any programs to encourage or enable small businesses to participate (e.g., special membership services, newsletters, seminars/workshops, etc.) at the ERC?

(12)

1. [2] No -----> SKIP TO 21

2. [1] Yes

20. Please provide a brief description below or include separate descriptive materials of the programs to encourage or enable small businesses to participate in the center.

(13)

21. If you have any additional comments you would like to make on any of the subjects covered in this questionnaire please include them here.

(14)

Number of Industrial Respondents, by Research Area

Research Area	Number
Aerospace	7
Automobiles and components	10
Biochemicals and biotechnology	16
Chemicals	5
Communications	7
Composites	18
Computers (hardware and software)	14
Construction	3
Dies and castings	8
Electronics and optoelectronics	8
Energy-related	
Combustion	6
Fuels	6
Utilities	5
Engines (aircraft, diesel, turbine)	6
Environment	3
Machinery	2
Manufacturing (unclassified)	4
Materials	4
Metals	11
Pharmaceuticals	6
Semiconductors	4
Miscellaneous	
Image processing	1
Lubricants	1
Optics	1
Parcel delivery	1
Robotics	1
Tools	1
Unspecified	5
Total	**164**

Comments From the National Science Foundation

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

NATIONAL SCIENCE FOUNDATION
WASHINGTON DC 20550

OFFICE OF THE ASSISTANT DIRECTOR FOR ENGINEERING

JUN 22 1988

Mrs. Flora H. Milans
Associate Director
U.S. General Accounting Office
Resources, Community, and
Economic Development Division
Washington, DC 20548

Dear Mrs. Milans:

See comment 1.

The National Science Foundation is pleased to have the opportunity to review the GAO report on the management of the Engineering Research Centers (ERC) program. We have found no major points of disagreement. We have offered some suggested editorial changes and a few factual clarifications for your consideration. They are enclosed.

The Engineering Research Centers program found the course of the evaluation of its activities by the GAO to be beneficial. The program has devoted considerable effort toward developing a carefully prescribed set of pre-award review procedures and post-award monitoring/assessment procedures to assure equity across centers, high quality operations and adherence to the key principles of the ERC concept. Nevertheless, the independent assessment by the GAO personnel helped to further refine our thinking.

We found the survey of ERC industrial sponsors to be very informative and plan to discuss these findings at our next meeting with the ERC Center Directors as well as with our ERC Industrial Advisors Group. We plan to update your survey periodically through our own resources.

We commend the GAO for the quality of the staff assigned to carry out this task.

Sincerely,

Carl W. Hall
Acting Assistant Director
for Engineering

Enclosure

Copy furnished:
Ilene Pollock, GAO

The following are GAO's comments on the National Science Foundation's letter dated June 22, 1988.

GAO Comments

1. The suggested changes to the draft outlined in the enclosure to the comment letter were mainly of a technical nature. These have been evaluated and included where appropriate.

Appendix X

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.

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Lowell Mininger, Group Director
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John Perhonis, Evaluator
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GAO/RCED-88-177 Engineering Research Centers

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