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EVALUATION OF

THE ENGINEERING RESEARCH CENTERS

Panel on
Evaluation Criteria for the Engineering Research Centers
Cross-Disciplinary Engineering Research Committee
Commission on Engineering and Technical Systems
National Research Council

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PANEL ON
EVALUATION CRITERIA FOR THE ENGINEERING RESEARCH CENTERS

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SUMMARY

The Panel on Evaluation Criteria for the Engineering Research Centers (ERC) was formed to develop proposed criteria and mechanisms for use by the National Science Foundation (NSF) in evaluating the ERCs after their third year of operation.

Because the ERCs represent a new kind of research organization (in that they are cross-disciplinary, industrially oriented, and equally focused on research and education), there are no precedents for evaluation. The criteria used for evaluating research in the traditional engineering disciplines and in previous research centers may not necessarily apply. Therefore, the panel emphasizes that the evaluation process must be constructive, and that it should be conducted in such a way as to strengthen the ERCs and improve their chances of success. It is important that the evaluation be viewed as an experimental, evolving process, one from which NSF as well as the individual Centers can learn.

Three background requirements focused the efforts of the panel toward the identification of specific evaluation criteria: (1) that the research and teaching carried out by the ERC be truly cross-disciplinary in character; (2) that the research and teaching be responsive to the emerging opportunities and needs of the international marketplace; and (3) that the research and teaching lead to an improved ability to rapidly translate research into competitive processes and products. A close and substantive interaction with industry is a vital prerequisite for the last two requirements in particular.

The panel identified over 100 specific criteria that it proposes should be used in the evaluation. These seven categories of criteria are as follows:

1. Research
2. Education
3. Industry interaction
4. Center leadership and management
5. Institutional environment and support
6. Interface with the research community at large
7. Overall considerations

Each of the seven categories includes both measurable and subjective criteria, with the subjective items phrased in the form of questions. A central conclusion of the panel, however, was that at this stage (and perhaps for the forseeable future) the ERC evaluations must depend far more heavily on the qualitative, subjective judgments than on quantitative, objective measures. Three years is too short a time to judge absolute accomplishments with any confidence; thus, the third-year evaluation must be anticipatory in nature.

The panel makes specific recommendations regarding the composition of the evaluation team, including the qualifications of the team chairman. It also proposes that site visits be conducted to carry out the evaluation. To this end, the panel recommends the schedule of meetings and suggests specific preparations that both the evaluation team and the ERCs should make in advance of the proposed visit.

INTRODUCTION

> During the third year of operation, the Centers will be reviewed by NSF and some of the initial reviewers. The review will determine if the Center is meeting the goals and objectives proposed, including the quality of research and the extent of industrial participation, and will be used to determine whether NSF will continue to support the Center fully for the remaining two years, or will provide decreased funding to terminate the Center at the end of the cooperative agreement.*

Purpose of the Report

In keeping with its plan described in the Program Announcement for Engineering Research Centers (ERCs) (see above), the National Science Foundation (NSF) asked the Cross-Disciplinary Engineering Research Committee to organize and conduct a meeting aimed at providing NSF with a set of criteria and mechanisms that it can use to assess the progress of ERCs. The Committee established the Panel on Evaluation Criteria for the Engineering Research Centers to undertake that task. This is the report of that panel.

Eleven ERCs have been established—six in 1985 and five in 1986. Although NSF assesses the progress of each center annually, it also plans to carry out a major evaluation of the ERCs during their third year of operation. NSF's request to the Committee is aimed at that three-year review. The intention is to test some aspects of the review criteria and methodology developed by the Committee during the second annual assessment of the first six ERCc, in 1987. The criteria and mechanisms for conducting the review can thereby be modified as appropriate before they are applied in the critical, comprehensive three-year evaluation.

Following a background discussion of the purposes and goals of ERCs, the advice and recommendations of the panel are presented in three major sections of the report—one describes the philosophy that should guide the evaluation process, another presents the recommended evaluation criteria, and a third describes the evaluation process itself, including the composition of the review teams. A brief conclusion offers a

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*From NSF Program Announcement, Engineering Research Centers, FY 1987, p. 3

perspective on the process and summarizes the main points that reviewers (and NSF) should bear in mind.

Background on the ERCs

The Engineering Research Centers program was inaugurated by NSF in 1985 to meet a need for cross-disciplinary research opportunities, for fundamental knowledge applicable to important national problems, and for preparing engineering graduates with the capabilities needed by today's technology-intensive industries. The ERCs are a direct response by NSF to what was and still is widely perceived to be an urgent national priority: increasing the competitiveness of our industries in the world market. The ERC program rests on the assumption that future U.S. economic competitiveness requires an enhanced ability to innovate and market high-quality, cost-competitive products in the face of increasingly potent foreign competition.

While the Centers emphasize cross-disciplinary research and education, they have not been established to supplant the existing disciplines. On the contrary, they depend upon the existing disciplines. Their goal is to pursue research and education that will result in a U.S. engineering community that is better able to take timely advantage of the work being done in the traditional disciplines and to integrate that fundamental knowledge with the future needs of our nation's technology-based industries.

PHILOSOPHY GUIDING THE EVALUATION

Breaking New Ground

The Panel on Evaluation Criteria for the Engineering Research Centers undertook its deliberations with a central fact in view: that the elements necessary for carrying out successful cross-disciplinary engineering research and teaching are, at present, not conceptually well understood. There is no consensus within the engineering community on what the criteria for success are. Within the traditional scientific and engineering disciplines, by contrast, the structures and patterns of success—and thus the measures of accomplishment—are generally underpinned by a consensus among the researchers and practitioners involved in those disciplines. Because no such consensus exists for cross-disciplinary research and teaching, learning how to accomplish those endeavors effectively involves pushing a new frontier. The categories of evaluation criteria used in the traditional disciplines cannot be automatically adapted to evaluation of the ERCs.

This panel, then, like the Engineering Research Centers themselves, is involved in an enterprise best characterized as a search. Lacking broad consensus on a successful methodology for

doing cross-disciplinary research and teaching, the panel must use its best judgment regarding what should be evaluated and how the evaluation should be carried out. The criteria presented in the following section rest on the assumption that the ERCs are experimental enterprises. A Center may demonstrate failure not only by trying unsuccessful approaches but also by refusing to try new approaches when the old ones have not worked. Likewise, formulating evaluation criteria cannot be a one-step activity. It must be viewed as a process. Doubtless, in the early period more of that learning will evolve from errors than from successes. The key is to sort out the mistakes and errors in order to find the mechanisms that lead to success.

It must be emphasized that the ERC program will succeed in the and only if it is sustained for a long enough time so that there are more successes than failures in that trial-and-error process. The program is still very young and vulnerable to harsh treatment. The panel believes that the evaluation process should be constructive and that it should be conducted in such a way as to provide guidance that will strengthen the Centers and improve their chances of success. However, it must also clearly identify Centers whose success is questionable at an early stage, so that failures do not waste resources that could be utilized more fruitfully.

Basis for Selecting Criteria

In formulating evaluation criteria, no danger is greater than the tendency to establish at an early stage rigid, highly quantitative criteria derived from familiar standards. The panel emphasizes this point because the pressures in that direction are likely to be powerful. They are of two kinds and originate from two sources. First, large organizations--certainly, large governmental organizations such as NSF--have a strong internal drive to establish measures that indicate success or failure over short periods of time. Second, within the universities and the research community more generally, those in established disciplines almost instinctively demand that all university programs be measured by the same generic criteria used in the disciplines. The importance of publication in established peer-reviewed journals is, perhaps, the best example.

There are three requirements central to the development of evaluation criteria, if the long-term goal of the process is to make the ERC program successful. First, it is essential that the research and teaching be truly systems-oriented and cross-disciplinary in character. We recognize that three is the danger that the funds provided for the Centers will be used to support research that would otherwise have been conducted in the context of the disciplines. Experience suggests that interdisciplinary enterprises very often lead to traditional kinds of research that are, for presentation purposes, merely packaged together with an interdisciplinary-sounding label. The critical ingredient in evaluating the ERCs is to ensure that the

integration of effort is substantive and purposeful, not cosmetic.

Second, if the new research and teaching is to contribute to technological competitiveness, it must be responsive to the emerging opportunities and needs of the international marketplace. Sensitivity to the opportunities and needs that that marketplace represents will most likely occur if there is close, continuing, and substantive interaction between ERCs and industry. Some cautions must be raised at this point. All too often industry is under pressure to emphasize the short term. Thus, one potential danger is that the ERCs could become "job shops," providing industries with help in solving immediate problems. Correspondingly, the ERCs must avoid focusing exclusively on existing markets; competitiveness demands attention to the evolution of new markets. Another danger is that university-industry relationships will be attractive in form but shallow in substance. The evaluation must ensure that there is close, continuous, substantive interaction between industry and the universities, that the participants from both sectors focus mainly on the long term, and that their collaborative efforts be mutually reinforcing.

In this last point lies the third essential ingredient for success: improving our ability to rapidly adapt and integrate new technologies into competitive processes and products. That is something quite different from solving immediate problems. It involves the design and operation of new processes and the conception, development, production, and diffusion of new products. This transfer of information and technology currently takes years, at the very least. The current goal of many corporations is to be able to move from concept to production in 5 years, with substantial business growth in less than the traditional 10-15 years. In fact, bringing a new idea to market has often taken 10 years or more. Therefore, the ERCs must develop a substantive industrial collaboration that is sustained over a long period of time. Technology transfer is not something that occurs primarily through publication. It occurs in the discussions and interactions of research groups and people involved with the development of ideas and information and the production and marketing of new products and processes. Both the Centers and those in industry who are associated with them, therefore, must take this long-term commitment seriously.

With these three overriding elements in mind, the panel believes that the early ERC evaluations must depend more upon qualitative, subjective judgments than upon quantitative, objective measures. Three years is too short a time for even the best-conceived, best-managed Center to establish much of a track record. The evaluation must therefore be anticipatory in nature—not a measure of products and profits created in industry, but rather an assessment of directions and vitality, a measure of short-term progress against long-term goals. If the standard of success is, ultimately, strengthening our nation's ability to innovate rapidly and cost-effectively, then the evaluation criteria must recognize that judgment will be a major ingredient. Meaningful evaluation at this stage must emphasize

the evaluators and the evaluation process at least as much as the specific evaluation criteria. Meaningful evaluations will require that those involved in carrying them out should be substantively knowledgeable about the area of research and training and also about the potential utilization of that research and of those trained in the Centers. Meaningful evaluations will require that those who do the evaluations understand the broad context of technological development and diffusion and international economic competition. Central to the success of the evaluation effort must be the opportunity for in-depth discussions between the evaluators and those in the Centers and in the participating industrial organizations.

The considerations that guided the panel in its selection of criteria can, therefore, be summarized in the following way. (1) The ERC initiative is attempting to meet the need for substantively different research and teaching—i.e., research and teaching that are integrative, cross-disciplinary, and synthetic in character and which address complex, higher order problems. (2) The criteria for judging success and failure of this cross-disciplinary enterprise must be of larger scope than the traditional, discipline-based criteria. (3) For the cross-disciplinary research and teaching to contribute to U.S. competitiveness close, continuous, and truly substantive interaction between universities and industry will be required. (4) Finally, success will require that those in both universities and industry maintain a long-term view and that they be looking at the possibilities of research and education that can contribute to technological innovation and leadership 5, 10, 15, or more years into the future.

RECOMMENDED EVALUATION CRITERIA

Approach and Objectives

Following the guidelines just outlined, the primary objective of the panel, in developing evaluation criteria for Engineering Research Centers, was not to produce a set of criteria aimed at identifying weak Centers and ejecting them from the program—although this is one purpose of the evaluation. Instead, the primary goal was to try to find those criteria that would help NSF and the ERCs to carry out this enterprise successfully. A basic premise was that it is better, at this early stage, to emphasize the qualitative over the quantitative; quantitative criteria lead too easily to distortion of the facts (and of the program itself) for the sake of a better "score." Indeed, what is easiest to measure is sometimes the least meaningful, in that numbers on paper may not permit the outside evaluator to distinguish a good program from a poor one.

The panel used a variety of sources in its attempt to generate a comprehensive set of evaluation criteria (see Attachment 1). The responsibility for sorting through the many

inputs, selecting the applicable criteria, modifying them if necessary, and developing new ones lay with the members of the panel.

We have listed the criteria in the following seven categories:

1. Research
2. Education
3. Industry interaction
4. Center leadership and management
5. Institutional environment and support
6. Interface with the research community at large
7. Overall considerations

These appear roughly in descending order of importance--certainly, the nature and quality of the research program, at least, is the sine qua non that determines success in all other areas.* Within every category but the last Measurable and Subjective criteria are listed. We recommend that evaluators use the measurable criteria as a starting point and as an entree into the more meaningful subjective assessment.

The subjective criteria are posed as questions. Many of them do not follow directly from the basic goals of the ERCs as posed by NSF, but they are nonetheless crucial. They are attributes that determine whether the Center will be able to achieve those goals successfully. Regardless of the specific nature of the question, the key background consideration (which evaluators should also keep constantly in mind) is the potential for the Center to have an impact on major goals such as the competitiveness of U.S. industries (both present and future).

Special Concerns

In their emphasis on cross-disciplinary research and education and on close university-industry interaction, the ERCs are a new kind of organization. Therefore, the question of evaluating them poses a number of special challenges. The panel had to consider how to evaluate and compare the crucial subjective aspects of an ERC. For example, how is it determined whether the Center has brought a change in culture to the campus or to the associated industries? How is potential industrial impact assessed? How is the creative synergy of a Center captured--Is the whole greater than the sum of the parts? Are the researchers really working as a team? Are the graduate students exposed to new ineights and challenges through interdisciplinary peer interactions? These things can be sensed, but they cannot be evaluated numerically.

Another set of concerns dealt with how best to determine the degree of substance in the industrial interaction. For

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*The panel did consider whether to further prioritize the criteria. The consensus was that doing so would contradict the evolutionary and subjective approach to the evaluation that is being recommended.

instance, is industry financial support the basis for a close collaboration on ERC-type research problems, or is recruitment and casual consulting the underlying purpose? Is the industry money "new money" for the university, or largely a continuation of a longstanding relationship? Is there a breadth of corporate interaction, including both large and small companies? Is there depth of involvement, so that the ERC has relationships with operating division personnel and not just the staff of the central research laboratories and headquarters of large companies?

The panel had to consider how the evaluation criteria should change over time for a given Center. It had to try to determine what distinguishes a "learning curve" from a "productivity curve" and to decide when the transition should be made from measuring effort to measuring achievement.

The net result of these considerations is, the panel believes, that the criteria must be flexible. We cannot easily anticipate the future requirements for competitive success in technology. Therefore, the criteria presented here, and those used in the actual third-year evaluation, should be subject to frequent review and modification as the technological environment itself changes.

Specific Criteria

1. RESEARCH

Measurable

- Number of publications (articles, books)
- Extent of cross-disciplinary authorship
- Number of patents
- Number of papers presented at meetings and where presented
- Conferences and meetings held as Center initiatives
- Citations worldwide of Center research
- Multidisciplinary involvement in research
  - Numbers of faculty from each discipline (engineering, science, other)
  - Joint faculty appointments
  - Other measures
- Number of visiting and associated investigators

Subjective

Technical

- What is the overall considerations quality of the research?
- Is the Center addressing the barrier problems in the field?
- How strong is the basic research thrust of the Center?
- Does the research do a good job of integrating science with the technology in question?
- What is the level of technological risk (i.e., probability of success) in the Center's research projects?
- Is there evidence of strong progress in the target field (breakthroughs, major broad advances, etc.)?
- Is the research contributing to the fundamental knowledge base?
- Is the research relevant to industrial needs and competitiveness?
- Is the research defining new market opportunities?
- What is the mix of long-term versus short-term projects?
- Is there evidence of international interest and involvement?

Cultural

- Is the research genuinely cross-disciplinary in nature?
- Are the problems being addressed difficult enough and/or large enough to demand a collaborative team approach?
- Is more being accomplished than would have occurred with an equivalent amount of individual research?
- Do the multidisciplinary teams function well in performing research and meeting Center goals?
- Does the Center encourage a diversity of research approaches?
- How are projects conceived? Is there input from a variety of sources--faculty, industry, students, others?

- Has the Center attracted high-quality people (including visiting scholars) to its research program since its inception?
- Are entrepreneurial spinoffs from Center research being seen?
- Are the research equipment and facilities of high quality and readily available to Center faculty and students?
- Is the provision of technical and maintenance support adequate?
- Are the research programs of the primary and affiliated universities well coordinated (if relevant)?
- Is relevance to industry needs an overt and consistent theme?
- Does the research emphasize the synthesis and integration of engineering systems? Is there a sense of a breadth of vision?

2. EDUCATION

Measurable

- Number of graduate students actively involved in research, per year
- Number of undergraduate students actively involved in research, per year
- Special degree programs offered and/or degrees granted, per year
- Number of new courses developed to complement the work of the Center
- Number of textbooks, videotapes, or other course materials produced for broad distribution
- Number of seminars and workshops on interdisciplinary topics
- Continuing education programs
  - Number of courses offered
  - Number of participants (total hours or other measure)
- Faculty commitment to education (full-time equivalent positions)

- Student opportunity for experimentation on advanced equipment (approx. no. of hours/student)
- Number of job offers by industry per graduate and average starting salary offer compared with engineering school average

Subjective

- Has the Center made substantial progress in codifying new knowledge?
- What is the quality of the graduate students in the program (NSF Fellows, Graduate Record Exam scores, etc.)?
- Based on the measurable criteria above, are graduates of the Center in demand by industry?
- Are students fully exposed to the cross-disciplinary aspects of projects, or do they stay within a specialty?
- Is emphasis placed on the synthesis and integration of engineering systems?
- Is emphasis placed on the team approach to engineering practice?
- Is emphasis placed on the management of engineering systems?
- Is emphasis placed on engineering ethics and values?
- Is emphasis placed on the relevance of research to industry needs?
- Do students gain a sense of the ultimate market (and the potential future market) with respect to research objectives?
- How do students evaluate the quality of the education they are receiving through Center research and teaching?
- Does the Center attempt to extend and explain the cross-disciplinary, systems orientation to other technical and science departments of the university, including other students?

3. INDUSTRY INTERACTION

Measurable

- Number of visits by industrial representatives, per year
- Number of visits to industry by Center researchers, per year
- Number (and percentage) of industry participants in Center research, per year
- Number of companies on advisory board
- Number of companies newly acquired as sponsors since establishment of the ERC (and as percent of total)
- Number of companies receiving regular information on Center activities and research findings
- Formal procedures in place for timely transfer of research findings to industry
- Tangible industry contributions to Center
  - Dollars (membership, licensing, subcontracts, gifts, etc.)
  - Equipment (types and market value)
- Number of adjunct faculty from industry (full-time equivalent positions)
- Gross annual revenues of member companies (average and range)
- Number of employees of member companies (average and range)
- Number of joint development projects, prototypes, etc.

Subjective

- Do industrial organizations have strong input (e.g., through advice and review) into Center research programs, plans, and direction?
- Is the interaction with industry effective and well coordinated?
- What is the overall considerations quality of the interaction process?

- Is the Center aggressively expanding its industry base? Has it attracted a significant proportion of new support sources?
- Are Center research findings efficiently transferred to industry in readily usable form? Are the terms of transfer reasonable?
- Do Center personnel interact routinely with industry operating division personnel (as well as central lab and headquarters staff)?
- Is the Center making its resources available to small and medium-sized companies? Are such companies represented on the advisory board?
- Is there a discernible impact on the economic strength of associated industries?
- What have industrial firms gained (in their opinion) through participation in Center programs?
- Has participation in the Center changed the behavior of the firms in any way—e.g., interactions with faculty, gifts or grants, continuing education, networking with other firms, etc.?
- From industry's standpoint, is the Center a cost-effective way to accomplish NSF's goals for the program?

4. CENTER LEADERSHIP AND MANAGEMENT

Measurable

- Obtain Center organizational chart
- Obtain Center budget figures
- Faculty augmentations vs. losses (measures of turnover)

Subjective

- Is the Center organizational chart logical and unambiguous, with clear lines of authority and responsibility?
- Is the director providing effective leadership of the Center?

- If the Center depends heavily upon the leadership of one person, is there at least one logical successor to that person?
- Is the research program being managed smoothly? Are there serious conflicts of time and interest?
- Is the management style conducive to collaborative, multidisciplinary research?
- Do the director and senior staff interact well with industry?
- Does the Center have a capable administrative support staff and procedures?
- Is the faculty fully committed (responsive) to the Center and Center management?
- How is funding distributed—along disciplinary lines? Who makes these decisions?
- Has the Center developed new sources of funding (i.e., beyond NSF and industry)?
- Where there is an affiliate university, is the collaboration substantive and well managed?
- Is there an ability, within the Center itself, to set criteria for goal attainment and goal measurement?
- Is there some provision for making and reviewing (and periodically revising) a "plan of attack" for the Center?

5. INSTITUTIONAL ENVIRONMENT AND SUPPORT

Measurable

- Obtain overall considerations university organizational chart, including that of the Center
- Obtain data on institutional funding for Center buildings and research facilities
- Number of promotion and tenure awards to Center investigators

Subjective

- Is the Center well integrated into the organizational structure of the institution? To whom does the director report?
- What are the director's management responsibilities with respect to the disciplines from which the faculty are drawn (e.g., is he or she involved in tenure/promotion/salary decisions)?
- Does the director have enough authority to get things done?
- Has the existence of the Center changed the parent institution or its policies in any way?
- Has the existence of the Center enhanced the reputation of the university in research and education (in the view of other universities, of industry)?
- Is there a high degree of interaction with other departments (schools, colleges) of the university?
- How do key academicians at the institution view the nature of the work and the quality of the participants in the Center?
- Does participation in the Center bring a faculty member into conflict with the reward structure of the parent institution?
- Has the institution made any long-term commitments toward the continued existence of the Center?

6. INTERACTION WITH THE RESEARCH COMMUNITY AT LARGE

Measurable

- Mechanisms in place to transfer research findings to other research centers, universities, and government laboratories
- Number of substantive meetings of director with other ERC directors
- Number of visits by faculty from other centers and universities
- Evidence of participation and interaction with state/local agencies and government laboratories

- Number of collaborative research projects with other institutions

Subjective

- Is the Center committed to maximizing the impact of its activities and philosophy throughout academe?
- Does the Center maintain close ties with other ERCs and with other research centers (academic and government) in its target field?
- Is an effort made to monitor the state of the art in the Center's area of interest, both nationally and internationally?

7. OVERALL CONSIDERATIONS

- How well is the Center meeting the goals established by NSF?
- Does the Center exhibit excellence in research and education?
- How strong is the Center as an organization?
- Is the Center having a discernible and positive impact on the academic engineering culture? On the competitive outlook for associated industries?
- Is the Center meeting (or exceeding) its own goals as set forth in the original development plan prepared for NSF?
- Does the Center show strong potential for continued growth in quality?
- Is the Center generally viewed by the faculty, students, administration, and industry affiliates as a dynamic, productive activity filling a critical academic/industry need?

THE EVALUATION PROCESS

In addition to developing evaluation criteria, the panel was also asked to recommend procedures for carrying out the evaluation. Accordingly, this section details elements of the proposed evaluation process, including its objectives, the composition of the evaluation team, and the mechanics and timing of site visits.

Objectives

The objectives of the evaluation process are time based. As was discussed under "Philosophy Guiding the Evaluation", at the three-year point the Centers cannot be expected to have reached maturity in terms of their research output, their educational programs, or their collaborative initiatives. However, they might reasonably be expected to have come a considerable distance from their starting point.

To gain a better understanding of what the objectives of this third-year evaluation should be, the panel developed an outline of what a review at each yearly milestone might encompass.

First Year:

- Institutional commitment
  - plan
  - program
  - focus
- Management issues
  - nature of resource allocation
  - advisory committee structure
  - position, space, funds

- Graduate student recruitment
  - From parent institution
  - From other institutions

- Faculty recruitment
  - From the university
  - From industry (adjunct, full-time, or visiting)

- Team building

- Initial industrial connections

Second Year:

All of the above, plus:

- Initial graduate student output

- Theses and publications

- Course development

- Continuing education offerings

- Actual availability of space and materials

- Extent of industrial involvement and investment

- Interest shown by industry (time spent on campus, etc.)

- Project selection and implementation

Third Year:

Focus on the change seen in elements listed above, plus:

- Entrepreneurial spin-offs
- Interinstitutional interaction
- Involvement of new member companies and smaller companies
- Industrial interest in results
  - Patents
  - Spinoffs, etc.
- Employment of graduate students
- International interest and involvement
- Progress on integrating experiments
  - Systems
  - Demonstrations
  - Prototypes
- Effectiveness of communication (mechanisms and content) with external constituencies

Thus, at the third year all the elements are only just in place, and development should be occurring across the board. It is difficult to say when a steady state would be reached; that will certainly vary from Center to Center. This is why we believe that the primary objectives of the evaluation must be to learn how such Centers develop, to identify their strengths and weaknesses, and to learn how to evaluate them realistically.

Team Composition

We recommend that the evaluation team be comprised of five to seven individuals, including a chairman. Team members should be chosen by the chairman in consultation with the NSF program director. The program director should act as visit coordinator, but the team itself should not include NSF personnel.

Collectively, the team should exhibit the following characteristics:

- Demonstrated technical leadership in the relevant field (with a cross-disciplinary composition)
- Expertise in management and organizational processes, including technology transfer
- Extensive industrial experience

- Extensive academic educational experience

The team should include people who are technically very knowledgeable, along with some who are less knowledgeable but very aware of research integration issues. Generally, the team members should be people whose experience disposes them to value group research achievement. It might also be useful for one member of this National Research Council (NRC) Panel on Evaluation Criteria for the Engineering Research Centers to be included on the evaluation team.

The chairman of the team should be selected by the director of the NSF's Division of Cross-Disciplinary Research. The individual selected should have demonstrated technical leadership in the field, with extensive industrial or academic management experience. He or she should be a good integrator of people and ideas and should have no conflict of interest (i.e., no direct involvement in that ERC).

Mechanics

The panel recommends the following steps for conducting the evaluation:

1. Center Preparation. The complete list of criteria should be sent to Centers ahead of time, with an explanation that the criteria represent examples of the kinds of things that might be asked during the site visit, so that Center personnel can be prepared to respond as substantively as possible. However, data relating to the measurable criteria must be supplied by the Center in advance of the visit if they are not already present in NSF's "Indicators" data base. (NSF will have to determine which information is needed.) The subjective criteria need not be answered in advance, but they are key criteria. Center staff should be prepared to address them in interviews and meetings.

2. Team Preparation. Prior to the evaluation, the evaluation team should have access to and should have read the following:

- NSF/Center Cooperative Agreement
- Site review/evaluation procedures and criteria
- Initial NSF site visit report (i.e., preaward report)
- Initial Center development plan
- Center future plans report (if any)
- NSF indicators data base, including data on technical output

- Representative research reports
- Summary of the Center's organized presentation (in time for the chairman to ask for modifications)

Arrangements should be made to ensure that the members of the team will have access to representatives of some of the Center's industrial sponsors—preferably off campus at the industry's facilities.

3. Interviews and Meetings On-Site. The evaluation team should be prepared to conduct a carefully planned array of plenary meetings as well as individual, task-oriented interviews. Emphasis should be placed on the latter, since close individual contact is essential to get an in-depth sense of the course of a project or to understand how the Center is organized and run, what degree of support it has from the university administration, etc. These meetings and interviews should be held with a range of individuals that include not only Center staff but also key non-Center faculty from the departments, students, university administrators, and industrial representatives (the last group is very important).

4. Exit Interviews. An exit interview should be conducted in a plenary session with the Center director and senior staff, along with key university officials. The purpose of this meeting is to permit continued fact-finding as well as feedback from the Center personnel on the evaluation process itself. A brief executive meeting of just the team members would serve to consolidate opinions and produce a consensus on the general outlines of the evaluation results.

5. Reporting. The team chairman should write the evaluation report, based on his or her own notes and on the joint conclusions reached by the evaluation team. The draft report should then be circulated to the members of the evaluation team for review and subsequent modification, if necessary. The revised draft should then be sent to the ERC director to elicit a response in the form of comments—on both the results and the process of evaluation. These should be taken into account, if appropriate, and the report should then be submitted to NSF. We would recommend that the NRC Panel on Evaluation Criteria for the Engineering Research Centers review all reports concurrently with NSF review of the reports.

Timing

It seems reasonable that the site visits could be conducted over a two-day period. The schedule might be as follows: Upon arrival, the team could begin with a working dinner. Day 1 would encompass the Center's presentations as well as interviews with the director, industry representatives, and university administrators and faculty. Day 2 would consist of an executive

session of the team and exit interviews with the Center's staff and university officials.

CLOSING OBSERVATIONS

The Engineering Research Centers program is an important venture. It promises to produce both engineering knowledge and knowledgeable engineers. Its goals reflect our nation's drive to restore U.S. industry to worldwide preeminence. In terms of national support for focused engineering research and education oriented toward the needs of industry, it has been a seminal effort and has been the catalyst for a similar effort by other federal agencies. A setback in this program would discourage future large-scale efforts by NSF and other agencies to stimulate the nation's engineering enterprise.

Competition among researchers for scarce funds is intense. A program with the size and national visibility of the ERC program becomes a likely target if it is not seen to live up to its expectations. That is why the panel believes that this evaluation should be conducted in such a way that it improves the chances of success of the program.

The established Centers are not in a contest among themselves, in which there must be winners and losers. There is a contest, to be sure, but the contest is a global one of international industrial competitiveness in product and process innovation, costs, and resources. In that contest there <u>are</u> winners and losers. The objective of this evaluation should be to achieve a stronger ERC program that will help to keep the United States in the winners' column.

Where evaluation teams find unusually attractive features or strengths in a Center's program, information about those healthy traits should be disseminated quickly to other Centers. Such findings need not wait for formal evaluation reports. They can be distributed in newsletters or videotapes.

Where a weakness in a Center's program is found and is acknowledged by Center management, arrangements should be made to monitor the Center's progress toward remedying the situation and improving its chances of long-term success.

As to the possibility of grading the Centers and comparing them with each other, the panel believes that we do not now know enough, and the Centers have not yet progressed enough, for an evaluation team to make the fine distinctions that are needed to do so. This is not to say that no Center should be dropped from the program. Although we cannot specify uniform criteria for determining failure, failure probably will be obvious to the evaluators, and the evaluation process should only confirm it. A lack of vitality, direction, coherence, and synergy in the activities of a Center should stand in glaring contrast to those Centers that are performing as hoped.

If the purpose of the evaluation is not to identify the winners and losers, then what, one might ask, is its purpose?

We see five purposes for this third-year evaluation:

1. to identify strengths and weaknesses in the individual Centers and in the program as a whole--i.e., as a part of NSF's learning process toward strengthening the ERC program;

2. to provide the basis for making mid-course corrections in individual Centers;

3. to help NSF learn how to perform future evaluations better;

4. to identify any obvious failures among the Centers; and

5. to give NSF information that it can use to justify the continuation of the program.

The panel's most important conclusion bears repeating: This evaluation of the Engineering Research Centers should be conducted in such a way that it improves the chances of success of the ERC program. If that is done, the expenditure of effort and time in the evaluation will be well compensated.

Attachment 1

Evaluation Criteria: External Sources

1. Cooperative Agreement established between NSF and each ERC.

2. NSF Program Announcement for ERCs.

3. Criteria used in evaluating the NSF-supported Materials Research Laboratories (prepared by the MITRE Corporation).

4. Criteria used by the New York State Science and Technology Foundation to evaluate its Centers for Advanced Technology.

5. Criteria used by the National Institutes of Health (National Cancer Institute) to evaluate research centers.

6. Criteria used by the National Bureau of Standards for their research centers.

7. ERC evaluation criteria and mechanisms suggested by Frank Press, President of the National Academy of Sciences, in Chemical & Engineering News (March 3, 1986).

8. Invited presentation: "Evaluation As a Constructive Process," Robert M. Lund, Boston University.