The National Science Foundation's program to establish engineering research centers in fields important to the nation's competitive position has given new impetus to interdisciplinary research on university campuses. Kicking off a series on interdisciplinary research centers that will continue in subsequent issues is an article by the head of NSF's Engineering Directorate and an interview with a current center director.

The ERCs: What We Have Learned

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Three years ago the National Science Foundaton launched a vigorous effort to link universities, industry, and government in an attempt to close the international competitiveness gap. This effort in support of Engineering Research Centers has become a major one for the foundation in modeling such relationships. In the coming year we anticipate about a fourth of the foundation's direct support for engineering will be directed to this program. I would like to share with the academic engineering community what we have learned in the short time of the program's existence and why we are so high on its potential.

Changing the Campus Culture—Why the Centers Are Needed

What was the rationale for establishing the Engineering Research Centers? We established this program to change a culture—the culture of our universities in their approach to education and research, and in their relationship to the users of their products, namely industry and society.

The ERCs were started three years ago to address three major objectives:

- First, to establish cross-disciplinary research efforts focused on a range of activities important to technological innovation and economic competitiveness.
- Second, to stimulate a cross-flow of information between university and industrial research groups by focusing fundamental research on current and projected industry needs;
- And third, to produce graduates who have a broad, industrially-oriented perspective.

The stimulus for the program was the realization that our engineering schools were becoming increasingly science oriented and concerned with analysis of narrowly focused topics at the expense of skills involving synthesis, such as design, optimization of engineering systems, and systems integration.

Many industry and academic leaders pointed out that the way we practice engineering in industry is very different from the way we teach our students. To ground them in experimental techniques and give them hands-on experience calls for more cross-disciplinary research and educational efforts.

The ERC program was put forth as one way—and I emphasize that it is just one way—to change a culture. The centers are a way to nurture new ideals, encourage innovation, produce better educated people, and promote stronger interaction among our institutions. The ERCs were established, then, as a corrective mechanism that could help

The ERCs At a Glance

Centers approved in 1985: University of California, Santa Barbara—*Robotic Systems in Microelectronics*; Columbia University—*Engineering Research for Telecommunications;* University of Delaware and Rutgers University—*Composites Manufacturing Science and Engineering;* University of Maryland and Harvard University—*Systems Research;* Massachusetts Institute of Technology—*Biotechnology Process Engineering;* Purdue University—*Engineering Research for Intelligent Manufacturing Systems.*

Centers approved in 1986: Brigham Young University and the University of Utah—*Advanced Combustion Engineering Research;* Carnegie Mellon University—*Engineering Design Principles;* University of Illinois, Urbana—*Compound Semiconductors for Microelectronics;* Lehigh University—*Advanced Large Structural Systems;* Ohio State University—*Net Shape Manufacturing.*

Centers approved in 1987: University of California at Los Angeles—*Hazardous Substance Control;* University of Colorado at Boulder—*Optoelectronic Computing System.* A fourteenth center, at Duke University, for emerging cardiovascular technologies, has been approved pending National Institutes of Health support.

NSF has promised each center support for an initial period of five years. The average annual award for each center ranges from about $1.5 to $3.5 million in fiscal year 1987. The 1987 budget for the centers is $30 million; the 1988 budget requests $48 million. With a total 1988 Engineering Directorate budget request of $205 million, the ERC program would be about one-fourth of NSF's total effort in engineering. The goal is eventually to establish 25 centers.

strengthen U.S. competitiveness in world markets. They were also seen as a means for industry to interact more directly with universities, both to communicate its research needs and to affect the educational background of the engineers it will hire.

We have built into our support an elaborate evaluation plan for the centers in order to measure their progress. The initial five years of support for each center (see details, p. 16) are, of course, contingent on satisfactory performance. We envision funding each center for a period of 11 years, after which time each should be self-sustaining.

What Has Been Learned

We have clearly established that engineering schools are eager to undertake cross-disciplinary research. Over the past three years, we have received 312 proposals for such centers from engineering schools, representing a request level of $4.6 billion dollars. Clearly, we catalyzed the university community with a concept whose time has come.

We have solid evidence that many schools benefited from the demanding experience of preparing a proposal, even though they were not funded. In some cases states have stepped in to provide support; and in one or two cases other federal agencies provided funding. Because of the opportunity to reap major benefits from relatively small investments, we anticipate that more states will use the ERC model in public universities.

We have learned that industry is tremendously interested in this type of interaction with universities, and that such an interest can be monetized. For example, about 125 industrial firms are putting up money and other resources to participate in this venture. For every federal dollar contributed, industry chips in $1.24.

Universities themselves are coming through with some of the backing necessary for the ERC program to succeed. Strong financial support is evident at all 13 institutions with centers. Some universities—Columbia, Delaware, Maryland and Illinois—have planned new buildings for the centers.

When we add it all up this may be the most significant lesson learned: We are convinced that for the U.S. engineering infrastructure to be strong, we must have a proper balance among cross-disciplinary research, single-investigator-initiated research, and research in traditional engineering sciences and emerging engineering fields. Cross-disciplinary research and education run counter to the current culture of most engineering schools. The ERCs have taught us that the cross-disciplinary research area is weak. It must be strengthened.

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The decision made to support the ERC concept was a bold move, not an incremental approach to tackling a problem. The program has demonstrated that other areas of engineering research and education, particularly those involving industry and academia, can benefit from a departure from "business as usual."

The ERC concept has the potential to reenforce—among both faculty and students—the idea that engineering entails lifelong learning and that learning is fundamentally cross-disciplinary. The most important goal of engineering education should be to develop in students an attribute that reenforces the ability to learn on one's own; that reenforces the fundamentals of science, engineering, and mathematics; and that reenforces the contributions of social sciences and the humanities on decision making. What can the ERCs do to develop such an attitude? They can involve students in problem definition, nurture the ability to learn on one's own how to get the job done and how to work with others who may not even be in the same discipline or field of inquiry.

Losing Sight of the Goal

This lesson learned brings us to a consideration of some of the problems. I say "problems" because I do not want to give the impression that all our centers are unqualified successes. Many are doing quite well but, like all programs that are starting up, we have our share of worries.

A major cause of concern is that some centers do not have vision. By *vision* I mean simply knowing where they are going and why. I'm not talking so much about indecision over what research to undertake—all the centers are attempting good research—but rather where the center should be three or five or ten years from now. Where should it be in relation to the larger community it serves—institution, state, federal government, industry, students?

To accommodate existing institutional power structures, some centers have lost sight of their goal. It is business as usual for them. Rather than a break with the past, a change of culture, the ERC is just an appendage on an existing base. It is not much different from what was there before.

I have my own opinion of why some centers lack what I call *vision.* Some fail to develop it because they are not doing the work promised in their proposals. Some have not expanded existing operations in to a new effort. And some have not emphasized the cross-disciplinary thrust so important in any systems approach to a problem.

Lack of vision is, I believe, why some centers have failed to project to *outside* entities what the center is and how it can be a catalyst for change. Industry, though key, is just one of these entities.

Reaching Out to Industry

All industrial sectors are not alike; some of the centers are dealing with highly fragmented industries. Their job is admittedly difficult. Like all

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centers, however, they must continually emphasize to industry that the purpose of industrial involvement is to focus the research on current and projected industry needs. Industry should not view its participation in the center as little more than an opportunity to get some research results and, maybe, a first cut at hiring students. The centers need to attract the financial resources of industry, but they also must attract industry's attention.

The ultimate selection of research projects must rest with universities. They must assume that the research conducted in the centers pushes the frontiers of knowledge forward. Industrial input can expand the horizon of academic researchers by bringing new issues and problems to their attention. The synergism that results when two cultures collide often provides the seed for major breakthroughs in both intellectual and the technological arenas. Long-term academic research based on a creative choice of research topics often yields significant short-term results. These research results can fuel parallel industrial endeavors.

In this connection, industry must get more involved in the debate about the research *as well as the education* to be conducted at the center. Decisions on research and education agendas should be deliberate and remain at the heart of the debate. Such participation is critical if the centers are to achieve one of their major objectives: to strenghten the cross-disciplinary emphasis in engineering research and bring the practice of engineering into the classroom and the academic laboratory. This is where the real payoff comes from the centers, where industry is made a full partner in the research and education plan. This is how a *vision* is developed.

Institutional Commitment

We are seeing wide variations in the commitment to the center by universities in terms of making the center a *visible* part of the university. The university must marshal all available resources in this effort—not only in the industrial community but in the state capital, regional governmental associations, and other areas of the federal establishment.

Many centers are not doing enough to gather in—or are not even aware of—so-called "non-traditional" sources of support. A university is a powerful organization in the community, state, and region. The centers must know how to tap into these sources under the "good offices" of the university. For their part, the universities have to reach out the to the centers and bring them much more into contact with such sources.

Summing Up

In commenting on the prospects for the centers, I'll go out on a limb and be unequivocal. I do not think the center concept is sufficient to regain our competitiveness. But I certainly think the concept—bringing together industry, academia, and all government levels in addressing engineering research and education—is a necessary one.

The center concept is growing. The Administration has proposed expanding it to basic science and technology centers in a wide range of scientific research fields in the 1988 budget. These centers would be established in fields such as computer and information sciences, materials sciences, and biology.

The Department of Defense has created a University Research Initiatives program, a multi-component effort designed to strengthen the capabilities of universities to perform research and educate scientific and engineering personnel in disciplines key to national defense. In fiscal years 1986 and 1987, the department spent $105 million to fund 86 multidisciplinary research efforts at universities. An additional $20 million was used to fund fellowships, young investigators awards, and scientific exchange programs between university and DOD laboratories. The department has requested $93 million in the 1988 budget for the University Research Initiatives program.

The states themselves are heavily involved in pushing the center concept. Usually a state identifies areas in which the university system has expertise and areas that are practically pertinent to the state's major industries. A research center is then established to focus on these technologies, with the state serving as a catalyst to bring private-sector and university resources together. Two years ago no fewer than 13 states were developing such technology research centers, and indications are that the effort has expanded significantly.

NSF's ERC program would achieve its ultimate goal and vision if all the 25 planned centers become the best intellectual, educational, and research centers in the world—centers where the world's best minds want to come to cultivate their talents and contribute to a new technological base.

NSF would have achieved its objectives if industrial firms depend on the outputs of these centers for their next move. Then the national network and infrastructure that will be established among these successful ERCs, single investigators at other institutions, and industrial firms will become a formidable national asset in the 1990s and the twenty-first century.

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