The NSF Engineering Research Centers and the University–Industry Research Revolution: A Brief History Featuring an Interview with Erich Bloch

Barry Bozeman[1]
Craig Boardman[2]

ABSTRACT. The NSF engineering research centers (ERC) program served notice of a sea change in university research funding and institutional designs, representing a transition from department-based, principle investigator-oriented university science to a new center-based model encouraging universities to work with industry and to work beyond the strictures of academic disciplines. In our view, the past three decades of U.S. science and technology policy have not seen an institutional change of greater importance. This paper begins with a brief history of the ERC program, including discussion of the program's origins, goals and research foci, growth, and influence as a model for other science center programs in the U.S. and abroad. Our "primary data" include an interview with Erich Bloch, former NSF director who was one of the chief architects and advocates for the ERC program. Because of the historical importance of this interview, we present the entire interview with the original material largely unaltered. We conclude with discussion of the managerial challenges that ERCs face within the context of traditional university structures.

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In 1983, in the midst of a perceived U.S. "competitiveness crisis," a National Academy of Science panel recommended that the National Science Foundation (NSF) establish interdisciplinary centers for engineering research. The resultant engineering research centers (ERCs) were not the first U.S. university research centers, nor even the first NSF-funded university research centers, but they nonetheless served notice of a sea change in university research funding and institutional designs, constituting perhaps the genesis of the multipurpose, multidiscipline, university research center (MMURC), depending upon one's definition (Bozeman and Boardman, 2003). Prior to the establishment of ERCs, there were certainly multidisciplinary, multipurpose and even multi-institutional NSF centers, but none approached the scope or scale of the ERCs. Whereas the NSF had experimented with centralized, university-based research centers with its materials science research centers and its industry/university cooperative research centers, the ERCs were different in goals, design and, not insignificantly, the magnitude of funding.

The goal of the ERC program to revolutionize engineering research and education by focusing more on interdisciplinary problems, building closer ties between industrial and academic research, and providing a different, more hands-on education for engineering undergraduate and graduate students. Engineering had been a stepchild of the NSF for many years but was soon to have its own directorate and already had its own NSF director, Erich Bloch, a professional engineer who had not only spent his career in industry but also never obtained a Ph.D., a first for the NSF director's office. The ERC program has indeed revolutionized engineering research and education. Not only has it influenced the way other federal departments and agencies approach the scientific and technical research problems which lay at the heart of their institutional research missions, but it has also fostered the establishment of similar research endeavors abroad.

The ERC program was, particularly at its inception, quite controversial. NSF was the house

[1]*Research Value Mapping Program*
School of Public Policy
Georgia Tech
Atlanta, GA 30332
E-mail: barry.bozeman@pubpolicy.gatech.edu
[2]*Research Value Mapping Program*
School of Public Policy
Georgia Tech
Atlanta, GA 30332

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of basic science. More precisely, it was the house of peer-reviewed, investigator-initiated basic science. Now, in the name of competitiveness, it seemed to some that the hallowed mission of NSF was being diverted. Worse, there was widespread fear that funds for small science, investigator-initiated projects, would be siphoned off for centralized centers operating not under traditional grants but under cooperative research agreements, a recently implemented expedient.

Today, one does not often hear the term "competitiveness" (though with a continued recession, the catch phrase may enjoy a revival) and the ERCs, now more than 20 years old, are no longer in the eye of the research funding storm. Indeed, the centers proved sufficiently popular that other NSF centers programs have been spawned, most significantly the broad-based science and technology centers (STC) program. Moreover, while the ERC and STC programs were in many respects pioneering, other large research funding agencies, including the National Institutes of Health (NIH) and Department of Defense, have bank-rolled a significant number of university-based research centers. When one adds to the list the many state government-sponsored university "centers of excellence" programs and the centers established by the universities themselves, one finds that the university research landscape has changed remarkably during the 20 years since the ERCs were a gleam in Erich Bloch's eye. In 1983, the academic department and its laboratories was the place where university research was performed. Today, there are hundreds of university research centers and about one-third of academic scientists and engineers are affiliated with a multi-disciplinary, and often multi-university, research center.

In our view, there has been no more important institutional change in the past three decades of U.S. science and technology policy than the movement from department-based, principle investigator-oriented university science to a new center-based model encouraging universities to work with industry and work beyond the strictures of academic disciplines. Most of the people who helped create this revolution are still alive and remain quite active. The purpose of our paper is to provide a brief overview of the development of the ERC and its impacts. Our "primary data" for the paper include an interview with Erich Bloch, former NSF director and former Presidential Science Advisor and, most important for present purposes, one of the chief architects and advocates for the ERC program. Before presenting the interview with Bloch, however, it is useful to provide a brief history of the ERC program.

1. A brief history of the engineering research centers program

Origins

In his contribution to the final report for the 1986 CETS[1] symposium[2] on future expectations for the then nascent NSF engineering research centers (ERC) program, George A. Keyworth II, Science Advisor to the President and Director of the Office of Science and Technology Policy (OSTP), described how the idea for the ERCs first came to light. It happened during a 1983 presentation made by the Committee on Science, Engineering, and Public Policy (COSEPUP)[3] to OSTP on the subject of computers in design and manufacturing. Keyworth (1986) explains:

> The presentation brought home to all of us how radically the role of the engineer will change in light of the tremendous information-processing capabilities that are emerging... After the presentation we were convinced that we should be doing more to help integrate engineering practice and training... and that our future industrial successes were going to depend on the availability of different kinds of engineers than those who had been successful in the past.

Following the presentation, Keyworth and colleagues, including George Low, president of Rensselaer Polytechnic Institute, turned to the National Academy of Engineering (NAE) to assemble a panel for developing new strategies with which NSF and the university system could transform the American engineer, who was up to that point believed to be focused on narrow, discipline-based topics, into a cross-disciplinary scientist and practitioner possessing synthesis-oriented skills such as systems design, optimization, and integration (Suh, 1986).

In February 1984, the NAE panel, comprised of engineering leaders from universities and industry, responded with a report, '*Guidelines for Engineering Research Centers*.' The report expressed the goal of a more hands-on approach to engineering research and education in terms of the broader U.S. mission of international competitiveness (Mayfield, 1987):

> The goal of the centers is to improve engineering research so that U.S. engineers will be better prepared to assist U.S. industry in becoming more competitive in world markets. Thus, engineering research and education must be judged by their success in achieving this linkage.

The tone of the report was appropriate to the times. Throughout the 1970s and into the 1980s, American industry was being outperformed by newly industrialized nations building niche technology infrastructures which, combined, proved formidable competition to the United States in the world industrial market. Korean steel, Japanese automobiles, Taiwanese electronics, and Indonesian aircraft set off a perceived "competitiveness crisis," both in the United States and in Europe, which is often credited as the catalyst for the ERC program. Consequently, the budget proposal to Congress for financial year 1985 included $10 million for ERCs, setting the stage for a new engineering directorate at NSF. After the first round of proposal solicitation and review in 1984, NSF funded six centers for 1985–1986. The goal then was for NSF to eventually fund 19 centers in addition to the original six.

Common goals, divergent research foci

In the 1984 *Guidelines*... report the NAE panel identifies two main goals for the ERC program. The first goal was to improve engineering research and education so that engineers training in American universities could more readily contribute to engineering practice once they graduated. The second goal was, by training engineers in more industry-relevant ways, to assist U.S. industry in becoming more competitive in world industrial markets.

The NAE panel advised that all ERCs should have three characteristics in common. First, ERCs should foster regular interaction among university engineers and scientists, including students, with their counterparts in industry to ensure that the research conducted in ERCs stays relevant to the needs of the engineering practitioner and, moreover, to facilitate knowledge flow and technology transfer between the academic and industrial sectors. Second, ERCs should promote interdisciplinarity in its research to bring together the knowledge, methodologies, and tools required for the engineering practitioner to solve problems important to an industrial sector or sectors. Third, all ERCs must have an educational component designed to attune future U.S. engineers to the needs of industry, specifically in terms of hands-on engineering research and education (Parker, 1997).

Despite these common goals and characteristics, the scope of the engineering research topics upon which ERCs focus is broadly diverse. The first ERCs, which emerged from the first round of proposal solicitation and review in 1984 and were established in 1985–1986, focused on the areas of systems research, intelligent manufacturing systems, robotic systems in microelectronics, telecommunications, and biotechnological processes (NAS, 1986). Since that time the research emphasis of ERCs has expanded to include such research foci as earthquake engineering research, environmentally benign semiconductor manufacturing, and subsurface sensing and imaging technology, to name a few.

Today NSF classifies all ERCs under one of four program meta-thrust areas for engineering research, which do not differ greatly from the research foci of the original six ERCs founded in 1985–1986. These meta-thrusts include bio-engineering manufacturing and processing (six centers), earthquake engineering (three centers), microelectronic systems and information technology (eight centers), and manufacturing and processing (five centers).

ERC program growth: Number of centers

At the outset of the ERC program there were six centers receiving NSF funds. By 1990, NSF had established 23 ERCs in addition to the original six, though many of these failed to qualify for renewed funding prior to the completion of the 11-year

Table I
Current ERCs (as of october 2003)

Thrust	Center	Lead institution	Link
Bioengineering manufacturing and processing	ERC for the Engineering of Living Tissues	Georgia Institute of Technology, Atlanta, GA	www.gtec.gatech.edu
	Center for Computer-Integrated Surgical Systems and Technology	Johns Hopkins University, Baltimore, MD	http://cisstweb.cs.jhu.edu
	Biotechnology Process Engineering Center	Massachusetts Institute of Technology, Cambridge, MA	http://web.mit.edu/bpec/
	ERC for Biomimetic MicroElectronic Systems	University of Southern California–Keck School of Medicine, Los Angeles, CA	
	VaNTH ERC for Bioengineering Educational Technologies	Vanderbilt University, Nashville, TN	http://www.vanth.org/
	Engineered Biomaterials Engineering Research Center	University of Washington, Seattle, WA	http://www.uweb.engr.washington.edu/
Earthquake engineering	Pacific Earthquake Engineering Research Center	University of California at Berkeley, CA	http://peer.berkeley.edu/
	Mid-America Earthquake Center	University of Illinois at Urbana-Champaign, IL	http://mae.ce.uiuc.edu/
	Multidisciplinary Center for Earthquake Engineering Research	University of Buffalo at Buffalo, NY	http://mceer.buffalo.edu/
Microelectronic systems and information technology	Center for Neuromorphic Systems Engineering	California Institute of Technology, Pasadena, CA	http://www.erc.caltech.edu/
	ERC for Extreme Ultraviolet Science and Technology	Colorado State University, Fort Collins, CO	http://euverc.colostate.edu/
	Center for Power Electronic Systems	Virginia Polytechnic Institute and State University, Blacksburg, VA	http://www.cpes.vt.edu/
	Integrated Media Systems Center	University of Southern California, Los Angeles, CA	http://imsc.usc.edu/
	Center for Subsurface Sensing and Imaging Systems	Northeastern University	http://www.censsis.neu.edu/
	ERC for Collaborative Adaptive Sensing of the Atmosphere	University of Massachusetts, Amherst, MA	http://www.casa.umass.edu/
	Packaging Research Center	Georgia Institute of Technology, Atlanta, GA	http://www.prc.gatech.edu/
	Center for Wireless Integrated MicroSystems	University of Michigan at Ann Arbor	http://www.wimserc.org/
Manufacturing and processing	ERC for Environmentally Benign Semiconductor Manufacturing	University of Arizona, Tucson, AZ (lead institution) in partnership with Arizona State University, the University of California at Berkeley, Cornell University, MIT, and Stanford University	http://www.erc.arizona.edu/
	Center for Advanced Engineering of Fibers and Films	Clemson University, Clemson, SC (lead institution) in partnership with MIT	www.clemson.edu/caeff
	ERC for Particle Science and Technology	University of Florida, Gainesville, FL	http://www.erc.ufl.edu/
	Center for Environmentally Beneficial Catalysis	University of Kansas, Lawrence, KS (lead institution) in partnership with University of Iowa and Washington University at St. Louis	http://www.ku.edu/~cebc/
	Center for Reconfigurable Machining Systems	University of Michigan, Ann Arbor, MI	http://erc.engin.umich.edu/

Source: http://www.erc-assoc.org/centers.htm.

award cycle (Feller *et al*., 2002). By 1994, 18 ERCs were operating. In 1997, another ERC was added, increasing the count to 19 centers. As of October 2003, there were 22 centers receiving funds through the ERC program. For a list of current ERCs and their thrust affiliation, see Table I. As of January 2002, 13 ERCs are self-sustaining after the conclusion of NSF support.

Since the ERC program's inception in 1984, NSF has awarded 56 grants to establish ERCs. Figure 1 tracks the distribution of these rewards by year.

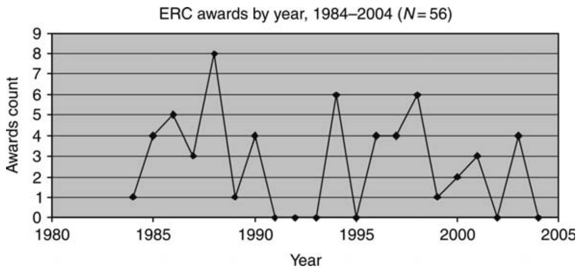

Figure 1. ERC awards by year, 1984–2004 ($N = 56$).[5]

An important observation to take away from Figure 1 is the discrepancy between number of awards granted and the number of centers currently receiving NSF funds. While some have graduated and are now self-sufficient, others have failed to successfully navigate the renewal process. (In the interview below, Erich Bloch indicates that these early closures actually had some positive effects.)

As of November 2003, 41 ERCs and three earthquake ERCs had been funded by NSF. This constitutes an historical ''survival'' rate for ERCs of 44/56, or 0.79.

ERC program growth: Magnitude of funding

Currently NSF funds approximately 30% of ERC total annual budgets, with industry, other federal agencies, universities, and the states providing the remainder (Lewis, 2004). The ERC program constitutes a substantial proportion of annual NSF expenditure on engineering research and related activities. In financial year 2003, ERCs and its spin offs received higher levels of funding than any other NSF engineering research endeavor, save SBIRs (small business innovation research). Of the $132.7 million that NSF spent on engineering education and centers (EEC) in financial year 2003 (see Figure 2, Table 3). NSF allocated nearly half, $65.72 million, to the ERC program. If this calculation is also to include NSF expenditure on Earthquake Engineering Research Centers, Nanoscale Science and Engineering Centers, and Science and Technology Centers, the amount increases by $19.89 million to nearly $86 million, or 65% of NSF expenditure on EEC and approximately one sixth of overall NSF engineering expenditure.[4]

Estimates for financial year 2005 demonstrate a modest decrease in NSF funding for the ERC program over the next year. To support a steady state of 19 ERCs, NSF has requested $63.49 million, which is down more than $2 million from financial year 2004 and down nearly $2.25 million from 2003.

The ERC Progeny

As we mentioned, the ERC program has served as a model for many other science center programs in the United States and elsewhere. Perhaps the most conspicuous progeny of the ERCs is the NSF's own science and technology centers (STC) program. In a 1987 letter to NAS President Frank Press, NSF Director Erich Bloch indicates that the STC program was a direct spin off of the ERC program (Metzger, 1987):

> Just as the National Academy of Engineering played a pivotal role in shaping the approach NSF used to establish and administer the Engineering Research

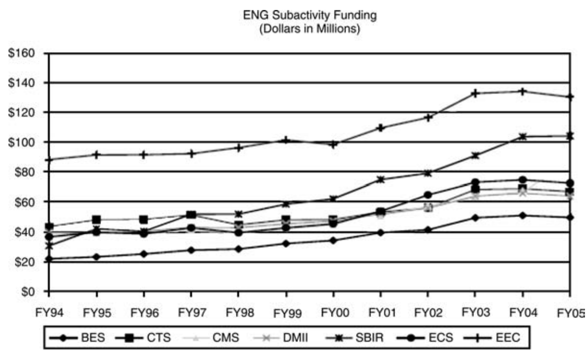

Figure 2. ENG subactivity funding (dollars in millions).[6]

Table II
ENG centers (dollars in millions)[7]

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent (%)
Engineering Research Centers	65.72	65.55	63.49	– 2.06	– 3.1
Earthquake Engineering Research Centers	6.00	6.00	6.00	0.00	0.0
Nanoscale Science and Engineering Centers	6.10	18.91	22.01	3.10	16.4
Science and Technology Centers	7.89	7.96	7.96	0.00	0.0
Total, Centers Support	$85.71	$98.42	$99.46	$1.04	1.1

Centers, a similar contribution can be made by the National Academy of Sciences with regard to this initiative.

The ERC concept has been extremely influential in other nations. For example, just a few years after the ERC implementation in the United States, the United Kingdom implemented a program based explicitly on the ERC model. The Science Foundation of Ireland (SFI) not only set up its program Centers for Science, Engineering, and Technology but recruited former director of the National Science Foundation's Science and Mathematics Division, Dr. William Harris, to serve as the SFI Director General.

One of many examples, a quite recent one, of the influence of the ERC as a model is a pending proposal, outlined in an options paper prepared by the Space Science Working Group, a group of space scientists and university government relations officers, for "university-based research centers modeled after the National Science Foundation's Engineering Research Centers" (Association of American Universities and the National Association of State Universities and Land-Grant Colleges, 2003, p. 1). This white paper on "NASA-University Workforce Development" seeks to expand NASA's ability to replace its rapidly retiring scientific and technical workforce with highly qualified next-generation scientists and engineers by having NASA "sponsor university centers, similar in structure to the Engineering Research Centers ... " and thereby establishing a "structure envisioned for NASA-supported university centers ... that would give both graduate and undergraduate students and opportunity to get hands-on experience in NASA-oriented skills."

From this historical context, we turn to our interview with the individual who is one of those most responsible for the university centers revolution, Erich Bloch (see inset).

2. Interview with Erich Bloch

We interviewed Erich Bloch in the late afternoon of May 22, 2003 in Mr. Bloch's Washington, D.C. office at the Washington Advisory Group, located at 1275 K Street. Previously, Bozeman had contacted Mr. Bloch and indicated we were interested in talking with him about the history of the NSF

About Eric Bloch

As Director of the National Science Foundation from 1984–1990, Erich Bloch helped originate and implement the engineering research centers program. Among all NSF directors, he was the first engineer and the first who did not hold a Ph.D. For these reasons, his appointment was initially controversial. Before his NSF appointment, Bloch was Corporate Vice President for Technical Personnel Development at IBM. He received the National Medal of Technology for developments that "revolutionized the computer industry," and is the recipient of the 2002 Vannevar Bush Award. Currently he is affiliated with the Washington Advisory Group where he advises on corporate R&D management and strategic planning for academically based research enterprises and other not-for-profit organizations. He is also serving as a member of the President's Council of Advisors on Science and Technology, and is the Distinguished Fellow at the Council on Competitiveness.

university centers programs, especially the ERCs and the STCs.

We feel this interview is of historical importance to students of technology policy and transfer as well as to practitioners interested in the history of university-industry relations in technology transfer. Given the importance of the interview, we present the entire interview and the original material is largely unaltered. Some notes (in parentheses) are provided in explanation. During the interview, Bozeman was the lead interviewer and Boardman the chief transcriber.

Bozeman: You were on the 1983 panel that published guidelines for ERCs. Did concept of the ERC crystallize before this panel got together? If so, how? Who were the primary actors?

Bloch: There was no starting point in the traditional sense. The whole situation when I was on that panel—which was before I went over to NSF—I think the whole focus was that in the engineering community (scientific) research was not associated with engineering. I knew about engineering, so I was appalled at this black and white idea of what engineering's all about. Out of this concern was our focus of relating basic research to engineering... to change both science and engineering cultures. A big proponent was George Low of RPI. (Dr. George Low was President of Rensselaer Polytechnic Institute from 1969 to 1984.) I think the general focus was what one can do to change this impression of engineering and to change the characteristics of engineering. But there was no particular singular event. But the timing was very important. If all this happened later there would have been less impact.

Bozeman: If there was no competitiveness crisis it wouldn't have happened?

Bloch: Yes that's my point. The coincidence of the ERCs and competitiveness crisis is what made it come to life.

Bozeman: In advancing the ERC idea, I understand there was one especially important meeting with George Keyworth (President Ronald Reagan's science advisor 1981–1985)?

Bloch: George Keyworth played a big role. From 1983 to 1984 I had many conversations with on competitiveness. We had a common concern. He participated in the semiconductor industry meetings. I was representative to those from IBM. His concern was that he saw lack of competitiveness in the semiconductor industry. This (was among the factors that) led to my becoming NSF director, my relationship with Keyworth and our common competitiveness concerns. Once NSF director, one of the first things I did was ERCs. Keyworth was more cautious than me. I wanted twelve, Keyworth wanted one. The idea needed to penetrate the whole engineering community. I thought twelve would send a message. So that was one rationale. Then when I looked at NSF (pause)... it was just the paymaster for PIs (principal investigators). I thought this was dead wrong. The idea was that NSF should be concerned about competitiveness and look for new avenues to tie together industry and government and universities. It was a new idea to NSF. The next step was doing the same thing for science centers, the STCs. But there were IUCRCs (Industry University Cooperative Research Centers) before all this.

Bozeman: So did the IUCRC's provide a sort of a template for the ERCs and the STCs?

Bloch: Not really. The word "center" has been used indiscriminately. For example, we have the Materials Research Centers, but these were more instrumentation centers than anything else. They had no formal mandated ties to industry. ERCs were a different animal. The culture of the centers is antithetical to the PI system. (When NSF implemented the ERCs) I suspected there to be more gnashing of teeth than there was.

Bozeman: The IUCRCs were around in 1978 with a similar mission as ERCs—at least on paper. Was there anything that you knew of from the IUCRC experience that you explicitly avoided when doing the ERCs?

Bloch: The ERCs are a different animal. They are much more research oriented. They are also broader in scope. IUCRCs drilled down to very specific topics. To me it was an entirely different program. Also, ERCs got a lot more money than IUCRCs. (note: the IUCRC budgets typically are \$100,000–\$200,000 per year). The two programs were not in conflict nor was one a continuation of the other.

Bozeman: Was there a cadre who got quickly on board? Was there NSF staff that played an important role from the outset?

Bloch: There was some staff that saw the need for change, but no one necessarily knew in what direction. Also, there were new people just coming in. Nam Suh was one of these. He was kind of torn. He grew up in a PI-grant world, but saw the need for changing direction. Also, the assistant director of biology, David Kingsbury (?) who knew exactly why there was a need for the change. Others like Bill Harris who have been here a while was a big supporter. Also there were many who opposed it. But enough of us agreed that something had to change.

Bozeman: At about the same time as the ERC concept was getting traction there was also a strong interest in some quarters to set up a National Engineering Foundation, entirely separate from NSF and, presumably, leaving NSF with no engineering programs. Did these two developments come into conflict or complement one another?

Bloch: I don't know if they played against each other. That's why I mentioned Nam Suh. We came to the conclusion that engineering was still in the 19th century. He was convinced that something had to change substantively. In some ways, it was not really helpful that George Brown (Member of the House of Representatives and Chair of the House Science and Technology Committee) was lobbying for a "national engineering foundation." He didn't get his engineering foundation. So a compromise took place. I'm not sure that these two changes were unconnected. I think they were quite connected. (The defeat of the engineering foundation helped provide the opportunity for NSF engineering research centers).

Bozeman: Outside of NSF, were others in government or in the science and technology policy agencies pushing for ERC's or some equivalent?

Bloch: George (Brown) was a big Democrat pushing for them. He had a lot of focus on it and was a senior member of Congress. The White House science advisor (Keyworth) was also focusing on it. The OMB was in the middle of things, but chiefly because they were against allocating more money, especially Stockman (President Reagan's Office of Management and Budget Director).

Bozeman: Was the issue of ERC's or the engineering foundation on President Reagan's radar screen? Did you speak with him about this?

Bloch: No. Later NSF got on his screen with the doubling of the NSF budget.

Bozeman: Could you tell me about the progression of ERCs to the STCs? Was it easier to garner support for the STCs because of the ERC experience?

Bloch: There was more criticism with the ERCs than the STCs. The ERCs paved the way for STCs. The scientists saw the money available from the ERCs and this led many to back the STCs. Many powerful people, including many members of the NAS (the National Academy of Science), saw the success of ERCs and thought that this idea might work for science as well as it had for engineering.

Bozeman: (The ERCs proposal requests are quite general and do not specify particular areas of engineering or research foci). When setting up the ERC program, did you and others give much thought to a more targeted approach, specifying research areas of interest, rather than a traditional proposal approach?

Bloch: We did not target because we knew if you threw it right over (to the university engineering community) that we would get proposals from the desired targets anyway. There was a demand for it (becoming a center). So restricting options didn't seem right. (The NSF had other targeted programs before the ERCs). ... and it caused a lot more unpleasantness but didn't really buy anything.

Bozeman: I was impressed with the fact that the ERCs were created with no detriment to the rest of the NSF budget for engineering research? Was this a self-conscious strategy to develop support for the ERCs?

Bloch: No, we never made that argument. It would not have been believed. (University engineering faculty) argued that if there were no centers then that money would have gone to the existing programs and funding PI's in the usual way. That wasn't true, but that was the spin.

Bozeman: The ERCs have by now been in place for a long time. Have they veered from the original vision?

Bloch: No. There have been some small changes, but not from the original direction. The program has kept its focus on education, industry, funds matching, which I never thought would happen, and the sunset clause also. It's kept to these. Obviously it has changed in terms of selection mechanism, but... (no major changes).

Bozeman: Have there been developments that you have found disappointing?

Bloch: I wouldn't say disappointing. The number of centers did not increase to extent that it should have. I had the idea of 22–23 after four or five years. We could have been better off with more centers earlier. But you can argue against that... they need time to mature, etc.

Bozeman: In our own research (Bozeman and Boardman, 2003) we have conducted interviews with many ERC and STC directors. Most of the points raised are very positive but we have heard some complaints about NSF micromanagement and the amount of time required for administration. Do you have any thoughts about this?

Bloch: Look. I have no doubt there's micromanaging going on. You can't have an agency like the NSF without micromanagement. The only way to avoid it is to limit the number working in that office. However, the academic community is immature. Their view is "Just send me money and leave me alone."

Bozeman: Another point that some of the directors make is that the missions have become too broad, focusing not only on research but education, technology transfer and social issues such as minority employment and community outreach.

Bloch: Life is tough.

Bozeman: Our research seems to show that there is a great deal of variation in the extent to in which ERC's work with industry and their effectiveness with industry? Is your impression different?

Bloch: This is big problem (whether or not centers are actually collaborative). Some proposals build from ground up. Others take their existing interests and use the "stapling approach" (they simply repackage work that they are already doing). In the better centers the university takes a primary interest. So the way the university treats the center makes a big difference. It's a big source of funding for them (the universities). I told this to Harris the other day. (William Harris, director general, Science Foundation of Ireland, former Assistant Director, National Science Foundation). I was glad I was in charge for the first six centers. We learned a lot from the first two centers that closed, Delaware and Santa Barbara. In a way I was glad that not all the centers were renewed. It sent a message that centers need to work to the commitment and *have a plan*. (Bloch's emphasis) If you don't have a good plan, the work and commitment don't matter. You'll fail. Because of this (the early failures), I believe prospective candidates are more careful about implementation.

Bozeman: (The ERCs and STCs require that faculty appointed in the centers have tenured or tenure-track appointments elsewhere in the university, usually discipline-based departments). Some of those we have interviewed tell us that affiliation with an ERC or STC may be a double load for researchers. They say it is like having two jobs. Do you think there is a potential for burnout or undermining productivity?

Bloch: You can't have it both ways. The ground rule is a faculty member at the center has to be a member of a department... they can't just belong to a center. The problem isn't the centers it's the departments. I'm against academic departments. I think they should get rid of them. There is no such thing as chemical engineering or mechanical engineering by themselves. They meld. This dual responsibility you talk about is unavoidable. If someone can't take it then they should get out. It seems to me that it's up to the individual. I'm not so sure that centers are more prone to burnout than any other job.

Bozeman: How about this as a potential problem with the centers: We know most directors have limited managerial experience. Most have only managed research and want to continue to manage research. Many have little interest or skill in managing the day-to-day operations, personnel, and finances of the center. They often hire someone else to manage the other aspects and in some cases it seems that some managerial functions are just neglected. Our research seems to indicate that some directors are excellent managers and some poor. The center selection process doesn't seem to pay much attention to overall management ability but chiefly research management. Do you feel this is a problem?

Bloch: You can find this in any profession and in any industry. But I agree with you. There are management problems. Maybe (management ability) should be part of the review process...

but maybe not. But I agree that management ability can make a tremendous difference. Management styles is the issue here, not theories of management. None if this is about textbook management. If center directors managed by textbook theory it would be a disaster.

Bozeman: (The ERCs and STCs have "sunset" provisions requiring that after a certain period they become self-sustaining and NSF funding is withdrawn.) Let's turn to the sunset provisions. I think all the center directors understand why these are important, but some make the case that their center has a harder time becoming self-sustaining because their work is farther from the market or, in some cases, such as earthquake engineering, there is very little potential market. What do you think about these views?

Bloch: Wait a minute. First, the sunset is very simple. It was put in place to make sure that centers find their feet. The second reason was to deflect from the idea of promoting bricks and mortar centers and ever-expanding centers. The idea of the sunset was at that time was that the centers should show fruit or die ... but there's a provision that you could reapply in a new competition. Of course, you may lose next time around. A third good reason for the sunset is that the university should take over if they want the centers to continue. The university can help find new sponsors and new money. It was not the idea of the sunset to blow it up, but to make centers find other sources of support.

Bozeman: Thank you for your time. This has been very helpful. I have just one last question. Now that you know what we are trying to get at, is there anything I should have asked that I didn't ask?

Bloch: You want me to do your work for you? (Bloch laughs). I don't know. What would be interesting is to see not only how these centers developed, but at this stage what is their direction of development. For example, I am always embarrassed when someone asks me how many university centers there are. Nobody knows. NSF supports more than 350 centers. What are they? Where are they? Why are they? We need to bring more knowledge to bear on this. We need to develop a typology, a morphology of centers. Otherwise, how will we know if we are funding the right things? How will we know about the gaps?

3. The ERC management challenge

As can be readily inferred from the material above, Mr. Bloch was his usual candid self. We have no need to comment on the interview. Mr. Bloch's perspective and opinions stand on their own. However, we think it appropriate to conclude with what we feel is one of the greatest managerial challenges of multipurpose, multidisciplinary university research centers—balancing the sometimes conflicting missions and doing so within the confines of universities that have not yet taken Mr. Bloch's prescription to get rid of academic departments.

In our interviews (Bozeman and Boardman, 2003) with university center directors, one ERC director provided an especially cogent account of the managerial conundrum for the relatively new institutions: "I'm managing on the basis of a big carrot and a little stick. The director has no way to entice other than dangling money. The director has no power and influence like the departments have. People work together when they want to work together." Another ERC director echoed these comments:

> My biggest challenge is the diversity of faculty interests and getting people to work together. There is no question that this issue is the biggest struggle and requires the most time and commitment. When we are trying to add something else to their agenda, they have to be convinced to give up something else. They have to decide that they want to move forward in that direction. People are driven by their own self-interests, and if they recognize that what we want them to do is something they want to do—they will do it. That's why we try to offer opportunities to work with companies. This is something I can offer—opportunities to interact, external things with companies or maybe something we do at the Center, things like a seminar series or journal club—things that give them opportunities for interacting in ways they want to interact. Even though these individuals are very invested in their own research, they recognize the power of interaction. The capacity to make linkages is due to having the Center and providing facilities.

To some extent the jury is still out regarding the ability of these innovative institutional designs for research and education to co-exist with traditional university structures created hundreds of years ago and little changed since. But the revolution has begun.

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Notes

1. National Research Council's Commission on Engineering and Technical Systems (CETS).
2. The symposium titled "The Engineering Research Centers: Factors Affecting Their Thrusts" was held on April 29–30, 1985 under the auspices of CETS.
3. COSEPUP was a joint committee of the National Academies of Science and Engineering and the Institute of Medicine. The presentation was on then new information processing capabilities, such as that enabled by the 1-megabit RAM chip.
4. Total expenditure on centers divided by total engineering expenditures equals 85.71/541.7. See Table II.
5. Developed by the authors from NSF data from https://www.fastlane.nsf.gov/a6/A6SrchAwdf.htm N of 56 includes ERCs and Earthquake ERCs. It does not include STCs.
6. Figures for 1994–2003 are actual, figures for 2004–2005 are estimates. source: http://www.nsf.gov/bfa/bud/fy2005/pdf/fy2005_8.pdf.
7. Source: http://www.nsf.gov/bfa/bud/fy2005/pdf/fy2005_8.pdf.

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