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Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community

Transforming Organizations Series

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TABLE OF CONTENTS

FOREWORD

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On behalf of the IBM Center for The Business of Government, we are pleased to present this report, "Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community," by Barry Bozeman and P. Craig Boardman.

Since the creation of the IBM Center for The Business of Government five years ago, we have been interested in the study of new ways to operate within large institutions. A recent IBM Center report by William Snyder and Xavier de Souza Briggs, "Communities of Practice: A New Tool for Government Managers," examines the use of informal communities of practice as a new way to work within traditional hierarchies. In this report, Professor Bozeman and Mr. Boardman look at the evolution of the multipurpose, multidiscipline university research center (MMURC) as a new, more formal approach to organizing research centers in the academic community.

Bozeman and Boardman contrast the new MMURCs with the traditional university research center (URC) and academic departments, which tend to be more disciplinary and single-problem focused. In contrast, the new MMURCs are almost entirely problem driven and do not track closely to existing disciplines and established scientific and technical specializations. Because of this, Bozeman and Boardman conclude that the potential for the MMURC is great. They write, "The MMURC has the potential to harness the historical advantages of university research and at the same time transform university research into a mechanism for solving a broader and deeper array of scientific, technical, and social problems."

This report is aimed at two distinct sets of audiences. One is university officials and university administrators, including MMURC directors, who deal directly with university research centers. The second is government program managers who are either currently managing an MMURC or considering establishing one. The report presents reasons why MMURCs are a potentially important tool for the government to use as it seeks to collaborate with the academic community in addressing national problems. We trust that this report will be helpful and useful to both audiences as they face the challenge of marshaling the nation's research community to address large-scale science and technology problems that require an integrated research approach.

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EXECUTIVE SUMMARY

While the vast majority of American universities are principally oriented toward undergraduate education, a new type of institution has emerged among the 150 or so "research universities" that lies outside usual academic core university departments and brings together several fields of science and technology for research and development purposes. The Multipurpose, Multidiscipline University Research Center (MMURC), together with its participating research universities, has become the starting point for policy makers looking for solutions to large-scale science and technology problems that require an integrated research approach. Often, MMURCs are created and called upon to play leading roles in programs that are critical to the national interest, which historically was the province of the federal laboratory system. More recently, they are playing a leading role in regional and state economic development.

In this study, we examine the historical forces that propelled universities into the "national laboratory" role. Our chief concern is not so much with the broad social and economic implications of these changes; rather, we are concerned with the implications for managing research and for innovation in research institutional design. To do this, we pay particular attention to the managerial challenges of two key actors in MMURCs—the research center director and the government program director—and devote the majority of this paper to analyzing responses to semi-structured interviews with directors of the National Science Foundation's (NSF) Engineering Research Centers (ERCs) and Science and Technology Centers (STCs), as well as other university research centers (URCs). Additional insight is provided from the results of more than 100 interviews conducted as part of case studies with URCs during previous studies.

The novelty and national significance of MMURCs provide sufficient justification for studying their management. Additionally, the evolution of MMURCs from the 1980s to the present brings to light unique management issues that make them fascinating subjects of investigation and analysis. First, MMURCs, like URCs, pose interesting management challenges because they are quite distinct from traditional academic departments in both purpose and organizational design. To complicate matters further, the relative newness of MMURCs means there is a lack of history and precedent in management styles and techniques. Third, many MMURCs are actually multi-university centers with a latticework of reporting relationships and authority lines to intra-university individuals and departments, inter-university individuals and departments, and outside (often funding) agencies. Finally, most MMURCs have significant industrial ties, often including an industrial advisory board or an industrial affiliates program, which further complicates their management responsibilities.

In looking at the evolution of MMURCs as institutions, the NSF's ERC and STC programs seem to have been particularly influential. Beginning with the ERC selection and funding process, we see that the NSF (like other funding agencies) has certain criteria to which the applicant must adhere not only in form but also in substance. Requirements range from formalistic procedures of submitting a letter of intent, preliminary proposal, and then final proposal, to a grander commitment to education and diversity in the country. The reason this is significant is that the requirements of the funding agency are strongly correlated to both the purpose of the MMURC and its management structure and policies.

Typically, directors of MMURCs are senior faculty who have been active in acquiring grants and publishing research. This is not only in keeping with the traditional route to URC management, it may also be a requirement of the funding agency (as it is with the NSF's ERCs and STCs). Additionally, most directors are the original principal investigator (PI) who submitted and won the grant or contract, and this seems to provide a greater level of authority than those who are not the original PI. Next, the center director's previous experience may also determine the university's grant of authority. Last, there is no uniform reporting structure for the directors; however, our surveys indicate that this was less problematic than we would have expected.

There is some variance in center directors' concept of their management duties, with some focusing chiefly on research management and delegating most other management tasks (at least to the extent possible) and others having a more balanced set of management duties. On the other hand, there is much more in common with respect to their formal structures and positions, which is largely due to the NSF structural requirements.

Compared to the free-flowing and almost completely autonomous and decentralized research organization style of most academic departments, the centers are more structured in their decision making. This is a result of the more specific mandates and expectations that the centers must meet with various stakeholders. Internally, there is often stiff competition for funds among projects, which can certainly be a challenge for center directors. The most difficult task, however, is managing the individual researchers, who seek independence and may have interests different from those of the MMURC. Of course, this frustration is in addition to the unique external communication obligations that the directors face with multiple parties that have different standards and expectations.

After analyzing the results of the study, we offer not only conclusions but also concrete recommendations on the management of MMURCs. We do so by offering two sets of recommendations—one for university officials and a second for government program managers.

Our recommendations for center directors and university administrators are:

- **Fit the reporting lines to the unique history and culture of the university**. There is no single rule about optimal reporting lines for MMURCs. While in theory one might assume that a large center should not report to a single dean or even department head but rather a provost or vice president for research, we learned that the success of reporting lines is better predicted by university history, strengths and weaknesses, and organizational culture than by apparent managerial rationality.
- **Have center directors focus on research administration and linkages; administrative directors should be empowered to make routine internal management decisions.** The smoothest running MMURCs are those where there is clear specialization of managerial tasks between the center director and the administrative director, with the former addressing primarily issues related to research direction and the procurement of funds and the latter focusing on tasks that do not require scientific knowledge and expertise, such as NSF reporting requirements and logistics for events like workshops and conferences.
- **Consider hiring a research management generalist.** Hiring a research management expert—someone with a Master of Business Administration or comparable degree, and perhaps industry research and development management experience—can facilitate interdisciplinary research activity.
- **Set aside a small percentage of center funds as seed grant money for underdeveloped yet promising research proposals, as a way of diffusing competition over center funds.** If there is no central decision making, then it is difficult to develop a center research niche or a strategic research portfolio. One of the ways

to develop a strategic approach to research but, at the same time, mitigate conflict is to have a set-aside for competitive award, perhaps complete with peer review.

- **Nurture collaboration among center members with regular meetings and multiple avenues of communication.** In multi-institutional collaborations (an attribute of MMURCs), it is easy enough for participating institutions to become absorbed by local concerns, with the result that the joint concerns of the collaboration do not receive ample attention. It is important to provide multiple communications opportunities among multiple communications media.
- **Cultivate industry partners interested in long-range relations and pre-commercial science and technology.** Generally, the best industrial partners are those who are interested in: (1) applied science that they can take to the next stage of development, (2) staying current with the latest developments in the field, with or without specific commercial objectives, and (3) working with the centers as potential employees for industry—for example, students and postdoctoral candidates.

Our recommendations for government program managers are:

- **Live (or die) with the university culture.** The comparative advantage of the university setting includes: (1) the ability to do truly cutting-edge research; (2) the availability of students and postdoctoral researchers; and (3) a large reservoir of diverse scientific and technical talent. But the university almost always carries liabilities. These include: (1) it is prisoner to the academic calendar, and faculty and students must tend to educational needs; (2) the reward systems for research are generally discipline based and oriented to refereed publications (rather than to a diversity of scientific and technical outputs); (3) faculty researchers are particularly impatient with administrative and accountability procedures; and (4) faculty researchers have their own research agendas and are not easily deflected from them. Government managers should expect to influence, at best, only incremental changes in the university culture, even in the MMURC.
- **Determine whether an MMURC or a more traditional university research center is the right fit.** Read the label. Not all university research centers are MMURCs. In many instances, the government program manager may find it useful to work with, or cultivate, a traditional university research center. The term *MMURC* encompasses "multidiscipline" and "multi-institutional." For some problems, a multidisciplinary focus and the resources of multiple institutions are exactly what are required. But the power of the "multi's" comes at a considerable cost. Even when center partners work well together, it is always more costly, and generally riskier, to work with a multi-institutional center than a single institution. Effective coordination is almost never achieved cheaply. By the same token, bringing together many disciplines on a scientific or technical problem, while certainly seeming like a good idea, is almost always more difficult than bringing together people from a single discipline. If scientists are from a single discipline, then they are much more likely to share work norms and aspirations, to understand one another, to respond to shared incentives, and to have a shared concept of quality. In sum, multidiscipline and multi-institutional may be exactly what is needed, but program managers must be aware of the downside risk.
- **Strive to minimize double duty.** Affiliation with an MMURC does not reduce the commitment to committee meetings, it expands it; it does not limit the time mentoring students, it increases it; it does not simplify the research and technology portfolio, it makes it more complex. Many of the faculty researchers we interviewed lived two interesting lives—one as a traditional academic, teaching and publishing in the discipline's refereed journals, and another working on the center's applied research and technology problems, perhaps working with industry groups and fitting into research teams composed of persons from a variety of disciplines and sometimes remote institutions. The chief point is that government (and center) managers must recognize the dual life and set expectations accordingly. Center researchers are "jugglers" with many balls in the air, and the price of the current organizational design is that

some of those balls will occasionally come crashing down.

- **Provide distinct management guidelines for centers, identifying potential pitfalls as well as responsibilities.** Government program managers should revisit and, if necessary, update these guidelines on a regular basis or whenever there is an apparent impasse between the program manager and a center. When mutually beneficial, it is important to allow for exceptions to these guidelines. Generally, guidelines are a better approach than extended requirements.
- **Find the right culprit.** It is often difficult for government program managers to know where to attack problems. Sometimes efficiency or effectiveness barriers are at the level of the center, sometimes the university administration, sometimes the state government, and, all too often, some interaction among them. These problems are compounded when the center includes many universities with their own distinctive management cultures. This is more a warning than a recommendation—program managers need to be patient in getting to the bottom of problems.
- **Do not encourage "shell collaborators."** In the cases we analyzed here and elsewhere, we concluded that most collaborations are valid and effective, but some are entirely window dressing. Shell collaborations consume vital resources with limited return. In most instances, government program managers will not be able to easily determine when collaborations will be viable (indeed, the center collaborative partners cannot be confident that collaborations will be effective). The key, then, is to scrupulously evaluate not just the centers but also the quality of the collaborations.

In light of the fact that so many of our recommendations seem cautionary, it is important for us to underscore that the MMURC is, despite the potential difficulties in management and design, one of the most important institutional innovations in (at least) the past 30 years. Both the scientific and management challenges of MMURCs are prodigious. But the possibilities for accomplishment are stunning.

Introduction: University Research Centers—The New "National Labs"?

American universities have transformed themselves. Not all universities—many continue with a primary, vital mission little changed from the 1930s: undergraduate education. But among the 150 or so "research universities," a new institution has emerged that we refer to as the Multipurpose, Multidiscipline University Research Center (MMURC). These centers lie outside the usual academic core of university departments, and they bring several fields of science and technology together, sometimes even helping create new fields. The MMURCs often play pivotal roles in new partnerships with industry and government. Many of these MMURCs are distributed networks for attacking national science and technology agendas in new ways and, in many cases, without the trappings of traditional university administration. Despite the fact that MMURCs tend to be overrepresented among elite universities, there is now a sufficient number of them as to dot every corner of the map of the United States.

Today's research universities and MMURCs often play leading roles in national science and technology programs critical to the national interest—programs ranging from defense satellite systems development to the National Nanotechnology Initiative. University research centers provide leadership in supercomputer development and the next generation of the Internet, in bioengineering and advanced medical technology, in earthquake studies, in climate change, and in environmental sustainability. In sharp contrast to previous decades, the university system is often the first place policy makers look for solutions to large-scale science and technology problems requiring an integrated research approach.

Historically, "grand mission" science has, in the United States, been the province of the federal laboratory system, especially the Department of Energy's multiprogram "national laboratories." During World War II and the Cold War, such laboratories as Los Alamos, Sandia, and Oak Ridge came to be synonymous with the development of nuclear weapons vital to the nation's national security. Later, many of these same laboratories were called upon to help resolve the 1970s energy crisis, conducting research on synthetic fuels and alternative energy sources. In the 1980s, federal laboratories were viewed as one of the possible solutions to perceived economic "competitiveness" problems, and programs were developed to enhance the ability of federal laboratories to transfer technology to the private sector and to partner with industry. More recently, the national laboratories have evolved again to help remedy environmental problems, such as global warming and climate change, and have taken on new responsibilities for hazardous waste cleanup and containment, including remediation of problems they themselves have created.

Despite the long-standing reliance on federal laboratories to perform interdisciplinary, problem-driven science and technology, dissatisfaction with the federal laboratories has grown, exacerbated perhaps as the end of the Cold War led to the widespread perception that the nuclear umbrella and mutually assured mass destruction were no longer keys to national security. When the federal laboratories took on such missions as technology transfer and environmental remediation, some believed this was more a sign of mission drift than of adaptation. A series of blue ribbon panels deplored the labs' alleged sense of lost mission, deplored their decline in science and technology capacity, and even questioned the need for their continued existence.

In the late 1970s, at roughly the same time as the federal laboratory system began its state of apparently endless siege, a companion development was occurring, one that was to fundamentally alter the landscape of the U.S. national research system. For the first time, policy makers were beginning to entertain the notion that U.S universities could serve as large-scale research "problem solvers" capable of taking on expanded missions, perhaps not (yet) the sort of grand-mission science associated with the national laboratory system, but certainly missions well beyond the stereotypical basic research, "research for its own sake," with which universities had been most closely identified.

Before the late 1970s, university research played a prominent and distinctive role in the U.S. research system, and university research was largely responsible for world leadership in many scientific fields. But the idea that the university, the very ivory tower itself, could provide leadership in research and technology development pertaining to the most ambitious national policy objectives was an idea few embraced. The idea that universities, among the most parochial of institutions, could successfully partner with one another, with government agencies, and with industry to catalyze new scientific and technical breakthroughs, and to then help develop the technology accruing from them, was a notion that few would have entertained. Universities were perceived as splendid purveyors of "small science," leading-edge basic research performed within disciplinary academic departments.

Are MMURCs the "new national laboratories"? If the criterion is a leadership role in national science and technology initiatives, then the answer must be affirmative. But universities are not yet entirely comfortable with this relatively new role. While some aspects of research universities are changing at a dazzling pace, many elements of universities are much the same as in the past. The disciplinary orientation, educational functions, and reward systems of universities differ little today from those of the 1920s. The administrative structure of many universities was developed to manage curricula, and many research administration structures have been added haphazardly, responsive to such jolts as changes in intellectual property rights, federal research accounting, and commercial enterprises of universities.

Acronyms

ERC	Engineering Research Center
MMURC	Multipurpose, Multidiscipline University Research Center
NSF	National Science Foundation
PI	Principal Investigator
STC	Science and Technology Center
URC	University Research Center

As we below will see, the MMURC came to prominence in the early 1980s, with the National Science Foundation (NSF) leading the way, especially through the creation of its Engineering Research Centers. While the NSF has continued it leadership role with this research institution innovation, many other federal agencies have since developed MMURCs and others are contemplating doing so. Likewise, state governments have developed MMURCs, often as a means of leading economic development initiatives. In this study, we examine the historical forces that propelled universities into a "national laboratory" role, but our chief concern is not so much with the broad social and economic implications of these changes but with implications for managing research and for innovation in research institutional design. We focus particularly on the managerial challenges of two key actors in MMURCs: (1) the research center directors, university faculty researchers who have a managerial challenge that is complex and in many respects unparalleled, and (2) the government program managers who pump very large sums of money into university centers and need to know not only about the impacts with respect to research problem solving but also the health and well-being of the research enterprise.

Some of the questions we consider:

- How do MMURCs differ from more traditional academic institutions, and where does the new research culture clash with the old one?

- How is the job of the MMURC director different from other research managers? How have managers of MMURCs handled the complexity and multiple roles of their centers and their researchers?
- How do policies of external sponsors (e.g., NSF and state agencies) affect the management of MMURCs? How do the policies of universities affect the management of MMURCs?
- What steps can be taken to support and improve the management of MMURCs?
- What is the domain of the MMURC? They are not appropriate for every science and technology issue, as reflected by the fact that they account for less than 10 percent of their respective universities' research budgets. For government program managers and policy makers managing a research portfolio, under what circumstances should the MMURC be a part of that portfolio?

We begin our analysis with a brief overview of this institutional revolution in university research administration.

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The Revolution in University Research Administration

Twenty years ago, the focal administrative unit for almost all U.S. university researchers was the academic department. Within the academic department, an organization devoted chiefly to teaching and administration of curricula, research activities were generally decentralized, focused on relatively narrow disciplinary objectives and aimed at the publication of articles in peer-reviewed scientific journals. This was the currency by which one gained tenure and continued a research livelihood.

To the extent research could be said to have been "managed," the management tasks were relatively simple ones, typically including supervising a small team of graduate students or postdoctoral researchers on tasks related directly to the production and distribution of research. Of course, even in the organizationally tranquil 1960s and 1970s, universities concerned themselves with federal accounting and budgeting and managing indirect costs, but these were tasks handled by a small number of university administrators, who insulated researchers from most managerial tasks. The job of the academic researcher was to do research and, if a faculty member, to teach and to attend to the routines of faculty governance and service. Every couple of years it was necessary for the researcher to traverse the federal grants system in an effort to sustain funding, but, for the most part, academic research was a professional enterprise entailing little bureaucracy and minimal management. Indeed, many chose academic careers, as opposed to often more lucrative industrial research, *because* of the greater autonomy and decentralization of academic research.

Today's academic research landscape is quite different, and the new more centralized, multipurpose, managerially complex research system has been in place for more than 20 years. While small science is still very much with us—the majority of grants remain relatively small, principal-investigator-initiated ones—small science now coexists with complex university research centers (URC) that have almost as much in common with large-scale industry research units or national laboratories as with traditional academic science. While the URC has been proliferating for some time, many represent relatively modest departures from traditional academic research organization designs. Many URCs are independent from departments, but simply provide a separate organization for supporting disciplinary researchers in pursuit of their traditional research and publishing activities. But we are especially interested in a particular type of URC, one that is multidisciplinary and multipurpose. These MMURCs are more complex inasmuch as they are organized around research topics rather than disciplines, they have strong inter-institutional ties, they often include researchers from industry and from more than one university, and, of special importance, the MMURCs present quite different and particularly interesting management challenges.

During the past 15 years, state governments have been quite active in setting up university research centers including many MMURCs. Many of these have scientific prominence and scope similar to the federal-government-financed MMURCs. For example, in 2000, the State of California approved the California NanoSystems Institute, a joint center of

The Georgia Center for Advanced Telecommunication Technology: A State Government MMURC

The authors of this report observe daily the operations of a state-sponsored MMURC because their offices are located in one—the Georgia Center for Advanced Telecommunication Technology (GCATT). In 1993, the State of Georgia created the Georgia Research Alliance, a program chiefly aimed at funding endowed chairs for university scientists and engineers and attracting them to Georgia universities. The legislation specifically set the objective of centers and research professors working with industry and helping spur new science-and-technology-based businesses. While the centers are not formally tied to a single university, the three created by GCATT are, in fact, co-located with universities and university personnel. The new GCATT building houses more than 50 Georgia Tech faculty and student researchers, and also is home to startup businesses and visiting researchers. One floor is occupied by members of Georgia Tech's Advanced Technology Development Center, a technology development, transfer, and commercialization enterprise. GCATT sponsors colloquia, speaker series, and a variety of forums attracting industrial researchers and managers, especially employees of Georgia companies working with one or another aspect of telecommunication and broadband technology. Most state university centers, including GCATT, resemble in some ways the federally sponsored MMURCs, but they generally have more concentrated and near-term economic development missions and almost always play an expansive role brokering local and regional industrial science and technology. But the state centers of excellence have much in common with other MMURCs and, again, very little in common with academic departments and their laboratories.

the University of California at Los Angeles and the University of California at Santa Barbara, funded at the level of $300 million. The state policy makers who created the center—perhaps the largest nano-science research institution in the world—hope that it will serve as the linchpin for a new segment of the California economy.[1] While the magnitude of the California NanoSystems Institute is perhaps unique among state-sponsored centers, most state governments have established university-based "centers of excellence" designed to promote the state's economic development (see "The Georgia Center for Advanced Telecommunication Technology").

The Management Challenge at University Research Centers

A great deal of effort has been directed to evaluating the MMURCs, not only with respect to their scientific productivity, but also the effectiveness with which they perform their technology transfer, economic development, and educational roles. The management of MMURCs has received much less attention, and with this study we hope to close the gap a bit and to show that the MMURC is an unusually fruitful target for management research.

The study of higher educational administration, including research administration, has a long history, but managing the new MMURCs differs greatly from managing traditional academic departments and laboratories. Department chairs and deans can look to at least 500 years of history and precedent as they tend to the management of curricula and research. In many ways, the line management tasks for today's university academic science line departments differ little from those of the 1970s. To be sure, grant systems have become more complicated and federal and state oversight more intense, but the academic science department is deeply anchored in a university governance system that changes slowly. Most of the same rules that apply to the classics department or the anthropology department also apply to the chemistry department. For example, the chair of the chemistry department generally reports to the same dean as the chair of the classics department. Likewise, the two chairs have very similar relationships to the faculty senate, the alumni association, the registrar, and the bursar's office.

There is no template for managing university science centers. In the first place, most of them are relatively new. Center directors cannot look to decades of history and accumulated procedure to determine how to do their job. Second, centers are not embedded in the university administration in patterned and predictable ways. A department chair or dean moving from one university to the next would find familiar hierarchies and lateral relations. But the MMURCs have been woven into

Example of an MMURC: The Center for Ultrafast Optical Science

While there is much diversity among MMURCs, one that is not atypical is the NSF-sponsored Center for Ultrafast Optical Science (CUOS) at the University of Michigan (www.eecs.umich.edu/USL/). CUOS is a research facility charged with national and international research leadership, producing lasers at the one terawatt level and laser pulses as short as six femtoseconds (6 x 10-15s) for a variety of scientific and technological applications. The Center owes allegiance to no single discipline and includes 26 faculty researchers from a wide variety of disciplines and departments, as well as more than 20 visiting researchers from industry, government, and other universities. Since the Center's founding in 1991, CUOS researchers have published more than 400 scientific papers. But technical application activity is no less important for CUOS than fundamental research, and the Center's research has led to new developments in laser-based microsurgery. Moreover, the designation as an NSF Science and Technology Center, and the Center's $3 million per year funding, requires not only leading-edge research but also industrial outreach and leadership in education, including training not only of doctoral researchers, but also of undergraduates and even high school students. The NSF Science and Technology Centers are also expected to provide leadership in the hiring and training of women and minority scientists. In short, like many other new university research centers, CUOS is extremely complex and multifaceted and bears little resemblance to a traditional academic department or research laboratory. It is not much like the physics or chemistry department in function, resources, mission, or longevity.

The CUOS facility is only one of perhaps 2,000 university research centers (Florida and Cohen, 1999), including several hundred that could be characterized as large-scale MMURCs, the organizational type of special interest in this study. The NSF-sponsored centers—including 12 currently funded Science and Technology Centers (and 19 that have "graduated," or exceeded their funding period) and 23 currently funded Engineering Research Centers—are perhaps the best known among the MMURCs, but they represent only a fraction of these new research institutions.

an existing administrative tapestry, and the patterns are not the same in each university. In one university, an Engineering Research Center reports to the vice provost for research; in another, to the dean of engineering; and in still another, to the chair of the civil engineering department. Most important, many MMURCs are actually multi-university centers with a latticework of reporting relationships and authority lines. In many instances, the MMURC director has cross-disciplinary and inter-departmental relationships to manage at a home university in addition to traditional hierarchical relations, but the director also manages inter-university relations. This same MMURC director generally has extensive external reporting requirements, to such diverse sponsors as NSF and the Department of Defense and, sometimes, to state government agencies as well. Finally, most MMURCs have significant industrial ties, often including an industrial advisory board or an industrial affiliates program. In short, the MMURC management task is almost always formidable.

The novelty and national significance of MMURCs provide sufficient justification for studying their management. But another feature of MMURC management makes them an especially appealing target for one interested in research management—the unusual means of "recruiting" center directors. In large industrial organizations and federal government laboratories, research managers typically spend many years doing bench-level science, and then begin a long management apprenticeship working their way up to increasingly responsible managerial positions. Likewise, traditional academic administration has a career ladder. The department chair is the first line management job, then associate dean or dean. The vice provost (or vice president) for research is almost always chosen from among those having extensive managerial experience at the dean or department-chair level.

The most common factor determining appointment to an MMURC director's position is an excellent reputation as a researcher, having served as the principal investigator (usually the grant writer) for the state or federal grant or cooperative agreement that established the MMURC. Some of these individuals have served as directors of other centers or as chairs or deans, but for many—and perhaps a majority—the MMURC director's position is their first foray into academic administration. To put it another way, the typical MMURC director is a very smart person, with no formal management training and little management experience, in command of a very large (at least by university standards) budget, and prisoner to the high expectations that accompany such funding.

Our previous work (Rogers and Bozeman, 2001; Bozeman et al., 1999) suggested to us that interesting things happen under such circumstances including, among other possibilities, managerial incompetence, re-inventing the managerial wheel, principal investigator structure run amuck, and—to a perhaps surprising degree—brilliant and effective managerial innovation. In this report, we explore in more detail what we have casually observed in studies that had other purposes (generally the evaluation of research programs). Here we consider the morphology and organizational design of these revolutionary science and technology institutions, the MMURCs, and their particular management problems, challenges, and innovations.

Perhaps most interesting to policy makers is that researchers working in the large, interdisciplinary centers we study are generally more productive than those who are not part of them. While differences in publication rates are modest, researchers working with centers do not publish more, but they have more external contacts, more research and technology development collaboration, and are more active in generating patents and licenses. In other words, their research is meeting the policy objectives set for them more than 20 years ago.

We have less evidence about the educational objectives of the centers, but we do have some interesting preliminary findings. In the first place, the researchers who have worked in industry and who conduct research with industry are, by some measures, better mentors for both master's level and undergraduate students (Bozeman and Corley, in press). They hire more students as research assistants and are more likely to collaborate with them. While there is little difference between traditional faculty's and industry-oriented faculty's work with doctoral students, doctoral students working at centers are much more likely to take jobs in industry.

In the organization of our analysis, we employ multiple analytical lenses. We use a landscape lens, surveying the MMURCs, their origins and history, and developing a working definition of and typology for the MMURC. Then we transition to a mid-range lens and focus on a particularly influential program for MMURCs, the NSF's Engineering Research Centers (ERC) Program. After focusing on the history and role of the ERCs, we use a portrait lens and focus on just one ERC, the Georgia Tech-Emory University Tissue Engineering Center. After providing this multi-level context, we have a sense of policy and institutional history and a specific institutional context, and the main body of the report considers the particular managerial problems, challenges and innovations of MMURCs based on interviews with directors of ERCs and Science and Technology Centers. Finally, in a concluding section, we consider managerial "lessons learned" and provide some recommendations about the design and management of MMURCs.

Origins of MMURCs: The National Science Foundation and "Competitiveness"

Before examining the role of research centers and their management, it is perhaps useful to provide a brief background to the role of academic research in the U.S. innovation system and the manner in which academic research is organized. In this section, we examine the growth of academic research as a source of U.S. research and development (R&D), and we contrast the traditional organization, by academic department, with the organization of research in university centers.

How and why did these new research institutions emerge? There are many reasons for MMURCs, including the increased cost of equipment-intensive science, the importance of interdisciplinary research, and the desire to change science and engineering education by making it more "hands on" and, accordingly, more involved with applied science and technology development. But among the many factors contributing to the changed university research environment, none is more important than the effort to harness university research to commercial objectives and national and regional economic development (Geisler, 1995).

While many government agencies have set up MMURCs, it is nonetheless the case that the history of MMURCs is interwoven with that of the National Science Foundation. In 1983, in the midst of a perceived U.S. "competitiveness crisis," a National Academy of Science panel recommended that the NSF establish interdisciplinary centers for engineering research. The resultant Engineering Research Centers were not the first U.S. university research centers, nor even the first NSF-funded university research centers, but they served notice of a sea change in university research funding and institutional designs, constituting perhaps the genesis of the MMURC, depending upon one's definition. Prior, there were certainly multidisciplinary, multipurpose, and even multi-institutional NSF centers, but none of them 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 was nothing less than 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 not only had spent his career in industry but also had never obtained a Ph.D., a first for the NSF director's office. And revolutionizing engineering research and education, the ERC program has accomplished. Not only has it influenced the way other federal departments and agencies approach the scientific and technical research problems that lay at the heart of their institutional research missions, but also the ERC program has fostered the establishment of similar research endeavors abroad (see "The Impact of the ERC Program" on page 16).

The Impact of the ERC Program

The ERC concept has been extremely influential in both the U.S. and other nations. For example, just a few years after the ERC implementation in the U.S., 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 the former director of the NSF's Science and Mathematics Division, Dr. William Harris, to serve as the SFI director general. Many of the centers that have developed in the past two decades in the U.S. and other countries have been modeled on the ERC program. 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 establish a "structure envisioned for NASA-supported university centers … that would give both graduate and undergraduate students an opportunity to get hands-on experience in NASA-oriented skills."

The ERC program was, particularly at its inception, quite controversial. NSF was the house 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 center 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 bankrolled 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. There are 14 large multidisciplinary research centers, including two Engineering Research Centers, just at our own university. 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 multidisciplinary, and often multi-university, research center.

The Morphology of University Research Centers

What is a university research center? That seems a simple enough question, but it turns out not to be simple at all. No less an authority than Erich Bloch, former NSF director, presidential science advisor, and farther of the Engineering Research Centers, lists this "simple" question as among those most important to our understanding of science policy institutions:

> I'm always embarrassed if someone asks me how many centers there are. Nobody knows. NSF supports 350 centers. But what is a center? They're all different, they are funded different ways. We need a typology of centers, a morphology.[2]

A definitive typology of centers is beyond the scope of this report; morphology is possible only

Table 1: Taxonomy of University Research Centers

Research Unit Type	Horizontal Relations	External Relations	Extra-Research Activities	Research Problem Focus
Academic Department	Minimal, except for those pertaining to curriculum administration	Simple and decentralized	Teaching, university and professional service	Discipline-based, provides consensus for rewards system
Simple URC	Simple, sometimes no significant ones other than to department	Simple, negotiated by researchers interacting with networks of other academic researchers and government funding agencies	Few or none	Based on narrow set of problems, usually established by discipline-based "normal science"
Complex URC	Simple, sometimes no significant ones other than to department	Moderate complexity, including not only academic networks but other knowledge user types, especially industry	More extensive, including an expanded educational role, or industrial outreach, or brokering diverse network members	Mix of problem-driven topics and topics set by discipline or field specialization demands
MMURC	Varies, usually very complex, cutting across many units	Complex, often including multiple external industry, government, and university actors	Multiple, often including educational role, industrial interaction, scientific and professional brokering, community outreach	Almost entirely problem driven, not tracking closely to disciplines and established scientific and technical specializations

after a great deal of systematic research of the population of research units at universities. But it is certainly useful for us to at least suggest some important distinctions among university research centers and to distinguish them from other types of university research institutions. We begin by providing a working definition of a URC as well as a somewhat different definition of the MMURC. These are elementary definitions, but we use them as a starting point.

We define a URC as *a formal organizational entity within a university that exists chiefly to serve a research mission, is set apart from the departmental organization, and includes researchers from more than one department (or line management unit)*. Thus, almost any formal research organization other than a department or a department-based laboratory meets this minimal definition, but an informal working group, even one with members diverse in their disciplines and departmental affiliations, does not. There is no requirement that a URC is interdisciplinary or multidisciplinary in its focus or that it is organized on the basis of research topic.

An MMURC must meet the requirements of the URC definition and, in addition, must pursue research on some basis other than shared disciplinary focus (typically by interdisciplinary research topic area) and must have a purpose in addition to traditional academic research (typically working with industry, promoting equipment and research resource sharing, or engaging in technology development and transfer). Even if a center reports to a single department chair through a line management route (most do not), it can nonetheless qualify as an MMURC. The reporting lines for the MMURCs often are a matter of historical accident, longstanding personal relations, or convenience.

Starting with these simple definitions, we can identify some of the most important variables distinguishing types of URCs and even types of MMURCs. Table 1 provides a rudimentary taxonomy based upon these critical variables.

University Research Centers and Academic Departments

A basic distinction is between the university research center and academic-department-based research. Before providing concepts of various types of centers, it is useful to begin with the venerable department-based organization, a scheme that has changed little in decades and remains extremely important. Even today, only about one-fifth of university science and engineering faculty are associated with research centers.[3] The vast majority of university research faculty conduct and administer their research as part of academic departments or laboratories administered by the departments. For those unfamiliar with the traditional structure of department-based research, a brief review of this traditional mode of research organization may be in order.

Academic departments are discipline-based units charged with teaching, research, and service missions. Generally, the three missions are intermingled, especially the teaching and research missions. As noted earlier, teaching is the major mission at all but a small minority of U.S. universities. Our focus here, however, is on the 150 or so universities that provide the preponderance of research output (articles, books, licenses, patents, and algorithms). Among the top research universities, research centers are more prominent, but most research is conducted and administered within the academic department.

Life in the academic sciences and engineering departments has much in common with research universities. Individual faculty members strive to the status of independent research entrepreneurs, measuring the arrival to that status by their success in attracting research grants and subsequently converting the resources that accompany research grants into research output and graduate student support and mentoring.

In a formal sense, grants and contracts are awarded to universities, not to individual researchers. There are many reasons for this arrangement, including an interest in insuring accountability, an interest in preserving institutional funds when researchers leave, and the need to take a broader view of university resources (including, for example, "indirect costs" for such expenditure items as scientific equipment, building maintenance, computing, and the heating and air conditioning of facilities). But the key research figure is not an academic administrator but the principal investigator. The principal investigator is the person who writes the proposal for the grant or contract, manages the resources, and is responsible for producing the goods and services (usually scientific research papers) specified in the grant or contract. In most universities, any faculty member can, in theory, serve as a principal investigator. However, junior (untenured) faculty and postdoctoral researchers are much less likely to have the experience and stature to serve as principal investigators. Thus, in the sciences, most junior faculty and postdoctoral researchers begin their careers working on the grants of others, often serving an apprenticeship.

In most research universities, the research role of the academic department is precarious. On the one hand, department chairs wish to nurture the careers of faculty, and this is chiefly accomplished by helping them to be productive researchers. But the department chair also is in charge of making sure that classes are covered by appropriate faculty and that students, both undergraduate and graduate, are well served. The mission is complicated by the fact that the research mission serves different types of students in different ways. Most undergraduates know very little about faculty research and, despite recent efforts at change, play little or no role in faculty research projects. When the faculty researcher receives grants and "buys out" of classes (i.e., the grant pays the university for the researcher's "release time"), the chief implications for undergraduates may be that they will never see the faculty member in the classroom and the class of interest either will not be available or will be taught by a part-time instructor or a graduate student.

By contrast, graduate students, especially doctoral students, not only have a role to play in faculty research but also are often supported by it, receiving a graduate stipend and tuition waiver for their work as research assistants. In the case of doctoral students, work on faculty research projects is often much more critical to their careers than their own classwork for official credit. In science and engineering, it is the doctoral research experience (and, increasingly, the post-doctoral research experience) that is an apprenticeship. If faculty are not successful in their acquisition of research resources and in their research output, the doctoral students' chances for success are diminished.

In sum, there are crosscutting, often conflicting objectives in the academic department. In the department, the researcher is tugged in several different directions at once, as is the department chair. A particular advantage for the faculty member is an extremely high degree of autonomy, especially in research. In a department, the faculty member generally decides his or her research agenda, the grants and contracts to pursue, and the allocation of work activity. The department chair and dean, the first-line and middle managers of universities, likewise have broad responsibilities and some authority, chiefly over the reward structure, pay, and evaluation, and play a shared role (with senior faculty) in promotion and tenure. The department chair and dean also have some resources to entice faculty researchers, often providing summer research money, supporting graduate student research assistants, providing research leave, and giving travel support.

One of the major features of departmental organization is that it can lead to a balkanization of effort. Departments compete for resources and research collaborations, and cross-departmental or cross-institutional activity can sometimes lead to a decrement of department resources either through lost research dollars or the lost time of researchers. Since departments are almost always organized by discipline (e.g., physics, chemistry, geology) rather than by problems (e.g., earthquakes, semiconductor packaging, tissue engineering), they sometimes provide, often unintentionally, disincentives for interdisciplinary and inter-institutional work. Or, to put it in a different light (the perspective of a department chair or dean), faculty entrepreneurs who have grants and contracts that ally them with other departments, other universities, and industry are less likely to be available to teach the courses for which students have paid tuition, are less likely to have sufficient time for such organizational maintenance activities as hiring and promotion committees, and in general have the potential to further tighten the tension wires among the diverse activities that academic units string together.

While the organization structure of academic departments varies somewhat, one can nonetheless isolate common features. Figure 1 (see page 20) provides a simple model for department-based organization of academic research. There are several key points to this organization. In the first place, department-based research reports through traditional academic line management channels (i.e., department chairs and deans), and thus promotes line management control of research administration (though certainly not of research itself). Second, research is typically highly decentralized. Principal investigators have their own small fiefdoms, sometimes organized into laboratory systems, and the principal investigators have direct contact with research sponsors (typically federal agencies) rather than depending upon line administrators to broker those relations.

Figure 2 (see page 20) presents a simple model of the organization of a research center. It is important to note that the organizational designs of research centers are much more diverse than those of academic departments, but the model nonetheless serves to highlight some distinctions between centers and departments. Perhaps the most important distinction is that centers typically have more interaction with actors external to the university, including industry, a richer variety of government agencies, and other universities. But they are also likely to have more and more important horizontal relations within the focal university because they draw resources on a "research problem basis" rather than on a disciplinary or traditional line authority basis. Often centers' research is more centralized, in part because of the fact that many centers receive what are essentially "block grants" instead of, or usually in addition to, principal-investigator-initiated grants.

Researchers in the center report to the director, but "report" has very different meanings in the centers since the directors generally have little or no role in tenure and promotion and sometimes little role in salary and performance deliberations. In most cases, the center director's role, relative to the department chair's role, is more limited in terms of internal management. "Limited" does not imply easier. The center director seeks to bring some order and cohesion to the center's work activity but has very little authority to use in negotiations with faculty members of the center inasmuch as the fac-

Figure 1: Model of Academic Department Organization

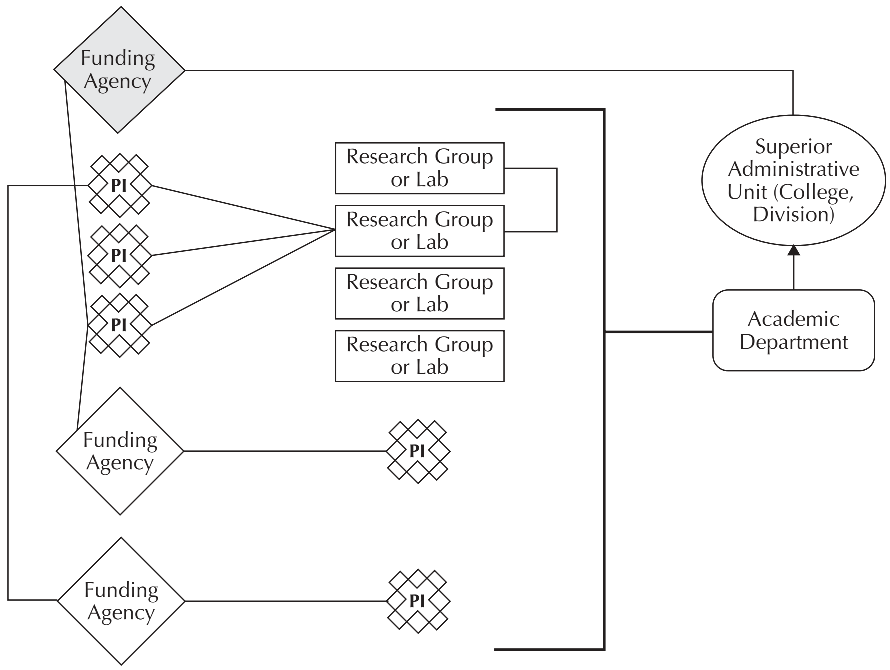
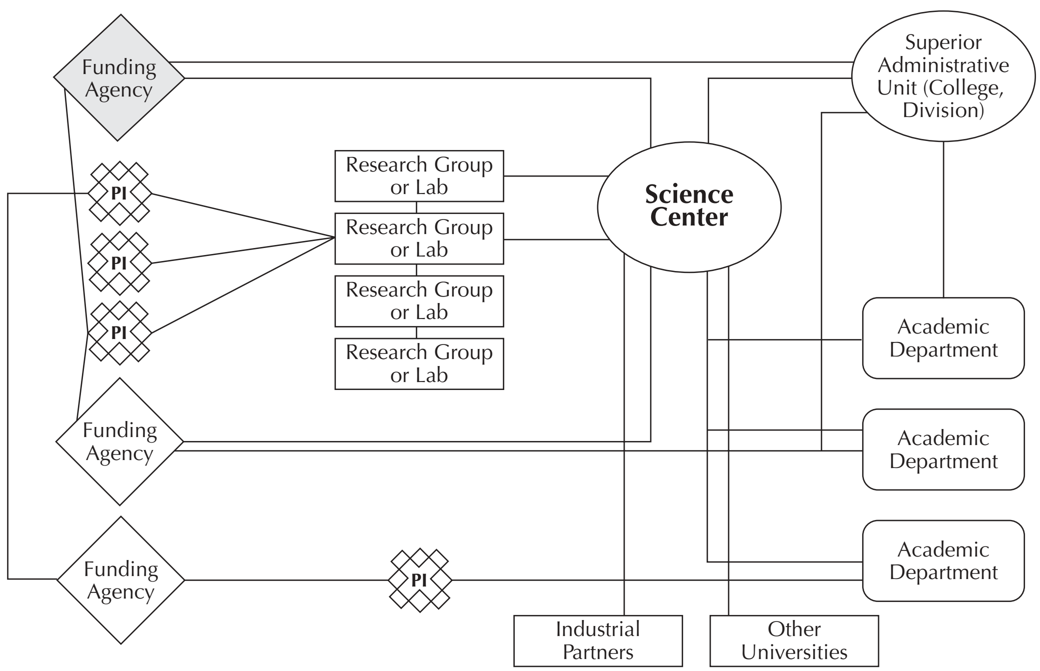


Figure 2: Illustrative Science Center Organization



ulty research likely receives pay from a different source, tenure and promotion from a different source, and generally has the option of unilaterally disembarking from the center. Compared to the department chair, the center director's external tasks are generally much more complex. Whereas the department chair must juggle the interests of faculty, staff, and students, and accommodate a dean, the center director often must relate to multiple departments, a web of university administrators, and, often, faculty and administrators from partner or affiliated universities, government sponsors, industry, and various accountability overseers.

Managing the NSF-Funded MMURCs: Evidence from Field Studies and Interviews

With the context provided in the previous sections, we now turn to management in the MMURC trenches to consider interview data.[4] Again, our primary research objective is understanding the management problems, approaches, and innovations at MMURCs.

The discussion below is organized into four parts. Our focus in the first section is on the NSF MMURC programs for Engineering Research Centers and Science and Technology Centers, respectively. The second section, a brief one, discusses the backgrounds of the center directors, their managerial experience, their reporting routes, and their authority. The next section examines centers' internal management, including budgeting, planning and decision making (especially with respect to research), personnel management, and reporting and accountability. The fourth section focuses on external management, including relationships with industry, the NSF, partner universities, and the center's own university. We pay particular attention to accountability issues inasmuch as the centers experience life in a "fishbowl" because of the amount of funding they receive and the relative importance of the centers in their respective fields.

Program Structure of the NSF-Funded MMURCs

There is no agreement as to the first MMURC or the first program for MMURCs. In part, the first MMURC is difficult to determine because there is no general agreement over the definition of the MMURC. But even if we use the definition we provided earlier, it is still not easy to agree upon the first MMURC. Perhaps it was the Manhattan Project. While we associate the Manhattan Project with Los Alamos, the project began in Manhattan (thus the name), strongly associated with Columbia University and later, under the leadership of Enrico Fermi, with the University of Chicago.

An even better candidate for the first MMURC may be the Massachusetts Institute of Technology (MIT) Lincoln Laboratories (Lincoln Lab). Created in 1951 as an MIT federally funded research center, chiefly with the backing of the War Department, Lincoln Lab focused on advanced electronics in air defense systems (see http://web.mit.edu/newsoffice/tt/2002/may15/lincolnlab.html). It seems to have met our MMURC definition inasmuch as it had significant external relations, with industry and with defense and national security agencies, and it brought a problem-focused, multidisciplinary approach to its initial work on air defense, including space surveillance, missile defense, battlefield surveillance and identification, and communications and air traffic control—all supported by a strong advanced electronic technology activity.

We are less concerned, however, with identifying the first MMURC or setting a chronology of MMURCs than with understanding the evolution of institutions. From this perspective, the NSF ERC and STC programs seem to us to have been particularly influential. The NSF certainly did not create the MMURCs. Not only had the Department of Defense and the Department of Energy created centers that could be viewed as MMURCs, but also by the early 1980s so had several state governments (e.g., the New

York Centers for Advanced Technology Program and the University of California's Multicampus Research Programs).

The importance of the NSF in MMURC programs is not in originating the concept but in its ability to influence the culture of academic research. As the only federal agency whose mission was specifically to support university research, the NSF has had a unique relationship with universities and university researchers. So not surprisingly, the NSF move to URC support initially sent shock waves throughout the American university system. The unique role of NSF, and the prestige that has been associated with their grants, has also increased the importance of NSF-sponsored URCs, and not only at the university. It has influenced the thinking of other government agencies and of industry about university research centers as well.

As mentioned above, the NSF ERC program began in the mid-1980s, making its first awards in 1985, establishing six centers, including the Center for Biotechnology Process Engineering at MIT (which thrives today, supported by grants and industry) and the Center for Robotics Systems in Microelectronics at the University of California at Santa Barbara (which was closed down before its term had expired). While the number of ERCs has expanded—there are 43 now—the basic structure of the program and its requirements have changed little since its inception. The most significant change in the program's requirements is that ERC requirements for education have increased, including a mandated outreach to pre-college students (at least at the "second generation" or renewed ERCs).[5]

The ERC selection and funding process begins with a yearly formal solicitation. The synopsis for the program solicitation is provided below:

> The Engineering Research Centers (ERC) Program is soliciting pre-proposals to establish at least two new ERCs in FY 2003. Each new center will focus on the definition, fundamental understanding, development, and validation of the technologies needed to realize a well-defined class of engineered systems with the potential to spawn whole new industries or radically transform the product lines, processing technologies, or service delivery methodologies of current industries. ERC faculty, students, and industry partners integrate discovery and learning in an interdisciplinary environment that reflects the complexities and realities of real-world technology and product development. This environment adds an integrative dimension that is enabled by the critical size of ERCs. Therefore, the National Science Foundation views ERCs as change agents for academic engineering programs and the engineering community at large. ERC innovations in research and education are expected to impact curricula at all levels from pre-college to lifelong learning, to employ and reach out to a population that reflects the diversity of the United States, and to be disseminated to and beyond academic and industry partners. ERCs play critical roles in research, education, diversity, outreach, and industrial collaboration. The absence of a compelling strategy for achieving demonstrable impact in any one of these areas is sufficient reason to deny funding.

Source: http://www.nsf.gov/pubs/2002/nsf0224/nsf0224.htm, downloaded June 3, 2003

The multiple objectives of the program (and the centers it funds) could hardly be clearer, and the admonition that "the absence of a compelling strategy for achieving demonstrable impact in any one of these areas is sufficient reason to deny funding" provides sufficient incentive for proposal writers to take each criterion quite seriously.

The ERC program requires letters of intent and preliminary proposals in addition to the final proposal. The competition is limited to U.S. academic institutions with undergraduate and doctoral engineering programs, though other university programs may join as partners. Both single- and multiple-university proposals are accepted, but most recent winners have been multiple-university proposals. The principal investigator (usually the putative center director) "must be a tenure-track or tenured faculty member in an engineering department at an eligible institution. In the case of a multi-institution ERC, the director must be a tenure-track or tenured member of the faculty of the lead university. The director's doctoral degree must be in engineering or a field of science."

Once the final proposals are received, decisions are reported within about six or seven months. The NSF program manager selects reviewers for the ERC proposals, and these reviewers include not only researchers but also industry users. The proposers may suggest possible reviewers. Appendix I provides the formal criteria for ERC awards.

Role of the Center Director

Center Directors Must Play Multiple Managerial Roles

Typically, directors of MMURCs, ERCs, and STCs are senior faculty who have been active in acquiring grants and publishing research. This is not only in keeping with the traditional route to URC management, it is an NSF requirement of both the ERC and STC. The ERC program announcement states that "the Center Director must be a tenure-track or tenured faculty member in an engineering department at an eligible institution." The STC program announcement has no such formal criterion for the director, but such requirements as a statement of current and previous research awards at least sends the signal that only those proposals with highly productive (in terms of research, publication, and grants acquisition) researchers are likely to receive awards.

While center directors share some attributes, particularly a high level of research productivity and status as a tenured faculty member, there is considerable variance in their backgrounds. Some have experience in industry, others do not; some have previous experience administering centers, others do not; some have experience as academic line administrators, others do not.

Most of the current directors served as the principal investigator for the original grant. The principal investigator, or PI, for a grant, contract, or cooperative agreement is the person responsible for performance of the research and other work stipulated under the agreement. Centers are set up with cooperative agreements, a special type of grant, one with broader authority.[6] The few directors who do not serve as the initial PI generally seem to have somewhat less authority and a more constrained set of duties. One director reports, "I put the center together." For this director, there is no stipulated term limit, only a long-range plan that the associate director will ultimately become director. Another director says, "This ERC was my baby." Again, there is no formal plan for executive succession, though there is a "disaster clause, in case I get run over by a truck." Contrast these seemingly stable and powerful directors' positions with another who was not the PI for the grant:

> I've been the director since the summer of 2001—so less than two years. I became director when the founding director left. The founding director was [a dean]. I joined the center during its second year.… [The director's position] is for a fixed term set by the vice provost. It can vary, but it is typically three to five years. There's typically a formal review.… In my case the circumstances are a little different. This is because the center has a grant that lasts five years and we have applied for a continuation grant for five more years. We agreed that my term would not go on after the first five years of the initial grant.

This same director also indicated that his position is half-time and that none of the staff reports directly to him but rather through two associate directors. In short, the power of this director was more circumscribed than any other we interviewed (either for this study or in earlier ones), but it is difficult to know whether these limitations are due to local circumstance, individual preference, or the fact that the director was not the initial PI for the grant.

The center director's previous experience may also determine the university's grant of authority. For example, the previous administrative experience of the more constrained director discussed above was director of graduate studies for a department of chemistry. Such positions generally entail little or no staff support, and thus limited supervisory experience, and often have no independent budget. By contrast, we can consider the experience of another ERC director who had founded and directed two previous centers and for more than a decade had served as chair of a large engineering department. Yet another reports that he "directed another center, an NIH center in the early 1980s involving instrumentation where each machine cost a half million to a million dollars."

A director of an STC compares his previous experience running a large university laboratory with running a small business:

> As center director, there's no question I used these management skills [developed running the laboratory]. When I ran the science lab here at the university, I managed a little over a million dollars. It was like a small business. You have deadlines for projects, renewals, milestones, etc. My skills were honed because I was the sole manager of students, people, and funds.

The diversity of reporting structures for the various centers is a bit surprising. We expected that the primary approach would be reporting to a vice president of research (or to a similar official whose duties cut across departments and colleges) because of the need to maintain flexibility and to work amicably with several departments. However, this proved to be only one of many reporting models and not the most common. None of the reporting models seemed to pose problems for the centers and their directors. In part this is because university administrators recognize that the ERC or STC brings a great deal of prestige to their university and that these new institutions have special needs that must be accommodated.

Several of the centers, even quite large ones, actually report to the administrator of a single department:

> My center reports under my primary department, which is bioengineering, and resides in that department. I report to my department chair and he is directly under the deans of the School of Engineering and the College of Medicine. We have not had problems because of good relations with the dean of engineering and the department chair and we don't really see much of the medical school dean.

While there would seem to be some disadvantages in reporting to a single department head, we found that, for some, the advantages outweigh the disadvantages. In particular, affiliation with a department can provide some flexibility in the deployment of resources and positions. The statement below provides an excellent analysis of the trade-offs of having an interdisciplinary center report to an academic department:

> Why is our center under one department? The center includes eight different universities, so in some ways it might be better if we were under a VP. There are pluses and minuses. I'm a professor of civil engineering first and center director second. We use the department and the department uses the center. We have the department to help us with accounting and the university grants office, and we share infrastructure. But there are some issues related to progress and review of doctoral students by a disciplinary group when working on broad interdisciplinary work. The department faculty may not give as much thought to broad thinking. This is a problem on every campus; they want to be more interdisciplinary, but departments are narrow. In the departments, it's still what awards do you have in your own discipline? If we reported to the vice provost, we would have more clout and more autonomy, and our indirect costs would not be shared with departments as they are now. But if we go outside the department, we pay rent. [Our administrative and reporting structure] works for us because we have one of the largest civil engineering departments. But it probably wouldn't work in a small department, where the center would overtake it. We get $4 million per year, but the department brings in $16 million of sponsored research.

The most common reporting line, however, is not through the department, but through a dean. Most of the ERCs report to the dean of engineering. Generally speaking, none of the different reporting relations (department head, dean, vice president for research, provost) seemed problematical.

Internal Management of Centers

Management Duties Differ but Are Key to Center Effectiveness

There is some variance in center directors' concept of their management duties, with some focusing chiefly on research management and delegating most other management tasks (at least to the extent possible) and others having a more balanced set of management duties. In the largest centers, the research management tasks, even if the director is more interested in research management, sometimes takes a backseat to duties pertaining to planning, resource acquisition, budgeting, and reporting. Some center directors seem to view themselves as managers who sometimes engage in research activities while others view themselves essentially as non-managers who conduct research and direct an administrative staff who perform management duties. To some extent, however, these differences are as much about self-concept as about actual differences in management activity. Several directors emphasized the important role of their staff:

> To run an ERC, you have to have a staff. I'm very fortunate. I feel that most universities undervalue the importance of staff, but I don't. I have an exceptional staff.… I spend more time with the staff than managing the research. There is a strategic plan, and we have three program areas—I'm in charge of one and others are in charge of the others. In overall management of the research, I probably don't spend a whole lot of time except through staff, and they are good.

Another director downplays his managerial duties, emphasizing research management:

> I'm not a pure manager. I'm just like other professors. I manage research. My management duties … I oversee some aspects of research, education outreach, finance, and industry. My deputy director is in charge of research. The deputy director is a Ph.D.-level position with the same research responsibilities as a professor.

NSF centers are required to be self-sustaining after two grant cycles. Some have considerable success after the "sunset period"; others have less or even disappear (see Gray, et al., 1987; 1991). Several center directors emphasized the amount of time devoted to fundraising and the need to make the institution self-sustaining after the sunset period:

> The most important responsibility is the future direction of the center and making sure we can do what we are supposed to do. I am responsible for growing the center and being on a steady course. After year ten we are supposed to be self-sustaining. The biggest responsibility is to keep it alive. The funding ends four years from now, but the pressure is now. It is one thing to get NSF money and another to get money from people who have not [previously] supported us. Much of my time is spent trying to get any dollars that are green.

Echoing this theme, another director noted that one of his biggest challenges is "getting funding for things that matter":

> Chasing dollars takes a lot of my time. It's not so much chasing but getting money for the right projects. An example of the wrong project would be having the center become just a research facility [a center for equipment]. There is pressure to do that, but it would take away from the research we want to do. We want to be a test bed, but not just a facility.

The centers have much in common with respect to their formal structures and positions. This is, in part, because the NSF has some structural requirements for centers (National Science Foundation, 2002). The NSF requires the designation not only of a center director, but also deputy or associate directors (who must have faculty status), faculty research thrust leaders, an administrative director (usually not a faculty member), an industrial liaison officer, an education program director, and a student leadership council. For the ERCs, the NSF also requires an advisory board of outside experts and an Industrial Advisory Board of ERC member companies to advise the director. Finally, centers must have an internal academic policy board to coordinate ERC plans and policies with departmental and university administrators and faculty governance committees. Thus, much of the formal structure is set by the cooperative agreement before the center is established. The centers vary in the ways and extent to which they use these administrative offices and apparatuses.

In nearly every center, the administrative director is a key figure, and the center's effectiveness depends, to a substantial degree, upon having a competent person in that position. The individuals occupying the administrative director positions vary a great deal; some have doctoral degrees and research experience while others have bachelor's or master's degrees, usually not in fields related to the research. In many cases, the administrative director is an experienced person brought in from an existing university research center. One administrative director describes her path to the position:

> I came to [this university] in 1987 and worked part-time in the Polymer Research Center. I came here because my husband came here. I worked at the PRC for seven years and then moved to [another research center], where I worked for four years. So that's eleven years doing this sort of work before I ever came here. I started working here at the center the day it opened. I had previous work experience in a multi-interest research center, but had never before worked with the NSF. The first thing I did here was read the proposal to the NSF for the center. Then I went through the "best practices" section for ERCs on the NSF website. The NSF manual gave me a good start.

It is worth noting that many of the administrative directors report that the best practices handbook is a major resource for them, especially at the beginning of their job. On the other hand, many of the center directors report only casual familiarity with the handbook. One administrative director noted: "I look at the handbook often but the directors do not; it is especially useful because it has recently been updated by people in the trenches, like me, and that keeps it relevant."

Most Center Directors Practice Participatory Management and Decision Making

Compared to the free-flowing and almost completely autonomous and decentralized research organization style of most academic departments, the centers are more structured in their decision making. But by comparison to government laboratories or industry, the typical MMURC decision-making style and structure are much less centralized and not nearly so hierarchical (see Crow and Bozeman, 1998, for a discussion of the organization and decision structure of diverse research units). The following description of MMURC decision making is fairly typical:

> We make decisions by our executive committee, setting out with our strategic plan. I try not to do this [strategic planning and decision making] all myself. The executive committee sets out criteria that suggest contributions and potential contributions not only in research but also education and outreach. Then we solicit proposals for not only research but also education and outreach. The proposals we get from faculty do double duty; we use them for deciding what we should be doing next, and we also use them in the annual reports. We have tremendous reporting demands, and we have to extract information.

Another center director described a decision process where many parties outside the center have substantial influence on decision making. The reason for an externally driven process is also clear—the need to keep a multidisciplinary focus on "consequence-based engineering."

> We have an internal "leadership team" made up of coordinators of research and outreach staff. [Persons outside the center] have quite a bit of influence on decision making. Our executive advisory board is made up of government and practitioner engineers. We also have [industrial] stakeholders who have to buy into membership. This [industrial affiliates program] is just starting up as a means of sustaining funds. The [center faculty and administrators] propose plans to the executive board and they

> give us comments. Then NSF brings in site review of a dozen people or so once a year, and they give us further advice, look at the future more than past accomplishments. The purpose is to reach a balance, to evaluate proposals in thrust areas. That way I don't have to come back and make unilateral decisions. We build consensus with the leadership team and the external reviewers.
>
> [With this input] we develop a final executive proposal. This is top down. We decide what problems we need to resolve … and these are usually interdisciplinary. We decide what we, as a group, want to study and then likely candidates and what sort of budget. Other centers seem to group talent and then decide what they are going to research—NSF looks negatively at that. Our center is very systems driven, not just fundamental research but where we need answers for problems and enabling technologies across systems. If engineers design one bridge at a time, this is not interaction. We do consequence-based engineering, and this needs to be interdisciplinary.

Despite the relatively collegial and participative approach that most centers take to decision making and research agenda setting, and despite the fact that the cooperative agreements provide substantial amounts of what is essentially block funding, there is nonetheless competition for funds. Not all ideas can be supported, especially when the center includes several affiliated universities. Some reduce conflict and competition by funding many small projects:

> Do we have competition for funds? Yes, absolutely. The researchers are in small interdisciplinary groups, and they annually submit a report that is based on the previous year's progress, and they can also submit a proposal for a new project. Anyone not currently involved in [the center] can also submit a research proposal. Then there is a review process of the proposal that is run by the co-director of research. That is followed by a review by the executive committee. I get involved only if I have to. Then, depending on our internal budget, we award funding to some of these projects.
>
> Internally, we usually have something like—over all of our programs—something like $1 million (including fringe and all that). We fund about 30 projects usually. They are pretty limited projects, though—they mostly support students and post docs. This is how we've chosen to do it.

Others diffuse conflict by elevating the role of outside groups:

> The Industrial Advisory Board [IAB] has the most say since it's their money, but I have some input. I also hunt down new technology and project ideas, but the IAB selects the actual projects to support. We're making [another university] a satellite institution for the center. There are individual project proposals from [the other university], and like us, they have some say with the IAB over which projects to go with, but the IAB still does the choosing.

Another common approach used for diffusing conflict about the allocation of dollars to projects is the director's "hold back." One director explained this process and also made the important point that money brought in by a faculty principal investigator is treated differently from center funds (and a recent study shows that PI funds have different impacts from center funds [Gaughan and Bozeman, 2002]):

> Sure we have competition over funds. I hold back about 10 percent of funds just in case that happens. When we start a new idea we do a seed grant, which is about $50,000, and we can fund four or five of these a year. I've never been forced to make [a unilateral decision denying funding]. I want to empower the people that run the programmatic areas and trust them in terms of making intellectual decisions. [Researchers have a known budget for the year], and we have an all-day meeting to see what will be funded. If they bring money as a PI, it is separate. The PIs, once

> they get their budget, are independent in a way, but projects [using center funds] are funded to be in line with the strategic plan that is devised by the leaders of the programmatic areas. So we try to create some integration with center research goals, even if an individual project is just a professor with a student. It is important for that student to see how that project is accomplished and how it relates to the center.

Managing Faculty Researchers Is More Difficult Than Herding Cats

Anyone who has served as an academic department head or dean knows that the old adage about "herding cats" is much too benign as a description of managing faculty. More apt is "herding feral cats" or perhaps "herding wild cats." Like feral cats, most faculty researchers prize, above all else, their splendid isolation. Like wild cats, faculty researchers have the resources to bite back. When one considers that studies of productive (high publication rates, high levels of citations, large number of grants) scientists have shown them to have low-intensity personal relationships, to be egocentric, and to be loners—and that the very best elite scientists are remarkably stubborn about embracing ideas not their own—the dimensions of academic research management come into relief (Roe, 1970). Consider the following about faculty researchers affiliated with MMURCs:

- They have their tenure vested in an academic unit that almost by definition has different norms from those of URCs (indeed, that is one of the reasons MMURCs were created).
- Their center affiliation is entirely voluntary.
- They may have large, independent research budgets.
- As center-affiliated faculty, they are doing double duty with respect to committee and administrative assignments.

Therefore, it is easy to see that center directors have no task more challenging than managing researchers.

An especially cogent explanation of the problem was offered by one center director: "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."

As each of the comments below shows, the center directors give particular time and attention to the challenge of getting diverse faculty to work with one another.

> 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 interaction 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.

Another director cites the most important lesson he has learned in managing a center—getting faculty to work together. He also explains why it is not easy to cull non-cooperative researchers.

> One of the realities is the intrinsic problem of bringing professors into a joint project and getting them to buy into it. Professors are hired for their independence. The management skill is in creating a vision that many can buy into and share.…I have to do sales work. I have to focus on the gen-

> eral value-added that people have gotten from the ERC and make sure they recognize the impact of our, say, $60,000 and get them to appreciate it. Some professors like our research money but go off and do their own research, not related to our strategic goals. It's not that their work is bad, but it just is not what we are trying to do. And we have a hard time cutting these people. The professors can stand the insult if we quit funding them, but it is sometimes really bad for the students working with them.

Directors of MMURCs are faced with a research faculty management issue not usually relevant to department heads or even many URC directors. The MMURC directors have as part of their mission developing external relations, particularly with industry. But some faculty researchers have little experience with this very different world.

> [A] consistent challenge is making sure that academics understand the business side to their research. It's hard to get them to focus on the work they need to get done. I have to be managerial and oversee their work and check to make sure they're going to meet their deadlines.

When we asked center directors about their most important management accomplishments or innovations, most had difficulty responding. Most directors view themselves as researchers who happen to be managing, and they view their accomplishments in terms of research currency and accolades.

In many instances, the director's perception of a "most important management accomplishment" pertained to personnel management innovations. For example, one center director told us: "What I feel most gratified by is our success in bringing together a broad range of disciplines. Certainly the work is not all done, but it's happening. It's hard though."

Another center director described his "most significant management innovation"—hiring an "MBA-type" research manager. This would not be considered an innovation in any industrial organization. But it is indeed an innovation in an MMURC where there is great faith in scientists and little in managers and where every PI is a king.

> For our renewal two years ago we restructured our research plan so that it would be attractive to multiple stakeholder (i.e., funding) groups, with multiple leveraging opportunities. We wanted to restructure but not hinder past research and accomplishments. Our objective was true interdisciplinary activity, not just words, in such a way as products would be valuable for stakeholders. We knew it would take an effort to get everyone on the right track. So we hired a full-time research manager to promote coordination and to know what they [center researchers] were all doing and where their results were going. Before, no one was really that accountable. It was more like a grants systems with academic researchers doing whatever they want to do at their home institution. You need oversight. The research manager does oversight and coordination 100 percent of the time. As a managerial advancement, this was pretty significant. [Gives name of research manager] is non-technical, he's not an engineer, but he had worked with other groups of researchers on campus. He has an M.B.A., but he had to learn about [the center's research specialty] and how it fits together.

Interestingly, this is quite similar to another local personnel innovation we studied at Oak Ridge National Laboratory, a Department of Energy multiprogram laboratory (Rogers and Bozeman, 2001). By having a master's degree level manager working full-time on coordination of a large superconductivity research and technology development project, it was possible to bring quite disparate researchers together with common objectives. In this case, the coordination even went so far as temporarily suppressing basic researchers' publications so that engineers and an industrial affiliate could patent and commercialize the joint work.

The difficulty of bringing disparate researchers together, and the extent to which directors' time and energy are devoted to the problem, is reflected in the fact that several cited this challenge as either their most important managerial accomplishment or as an innovation.

> We provide opportunities for people, and that pushes the whole program forward and also suits the individuals involved. The basic organization problem is how you set up research programs that will be optimal for pushing forward the science and technology, and how you at the same time bring together the right group of people with the right focus.

External Management of Centers

University-Center Relations Can Lead to Friction

In addition to managing their on-site center, each of the center directors has an assortment of relationships, both horizontal and vertical, to manage at their own university. In addition, many of the MMURCs are multi-university centers, and these multilateral partner relationships are almost always quite complex. Let us begin with the intra-university relations.

Intra-university relations are not always satisfactory. One center director assessed relations as follows:

> We struggle with day-to-day relationships within our institution. There's a lack of understanding. The provost is so far remote. The dean is remote. They don't understand the trenches at the department level. The main problem is between the center and the university administrators. It's love/hate. The center so far is reporting to the dean and not to individual departments. This creates problems. The departments don't understand why or what we have to do to succeed. The NSF knows this, but is not much help. The execution of communicating this is not so easy. The departments need to be constantly supportive. They need to be reminded that they have a responsibility to the center. NSF should consider this during review. They need to talk to institutions more carefully. They do meet with the dean for one hour or so. NSF micromanages the center. If NSF made a point to micromanage roles everyone has, then everything would be much easier.

This center director's grievances were notable chiefly because they were at variance with all our other interviews. For the most part, our interviews showed that a center's relationships with its university were as effective and often cordial. Consider the much more typical comments below:

> I haven't had any problems (in relating to the university administrative leaders). I have good relations with the dean of engineering and the department chairs.… We get support. The department chair who encouraged me to do the initial [center] grant is now the provost, so that helps.

The smoothness of relationships with departments is perhaps even more surprising. While some center directors and other center faculty noted the tension between center work incentives and rewards and those in the departments, it seems that center/department relations are otherwise either benign or even symbiotic.

How does one interpret this apparent lack of acrimony? If one considers the potential strains between centers and the other units on campus, then one expects unharmonious relations. The centers are, in a sense, in competition with the academic departments for the time of the faculty researchers. The centers often pursue objectives that are not completely in line with those of the departments. For example, few departments emphasize or reward ties to industry, apart perhaps from simply recognizing money brought in from university grants. And, of course, departments are notorious for underemphasizing both multidisciplinary work and, in most instances, applied work.

We think there are three important factors that mitigate a "natural" antagonism between departments and other academic units and the centers. In the first place, we are examining here only NSF-sponsored ERCs and STCs. These awards are extremely competitive and prestigious and, of course, bring considerable funding. Thus one might expect that universities would be more likely to accommodate the needs of these centers than other centers having less prestige and smaller amounts of money. In addition, universities generally are very much involved in the centers' proposals in a way that is quite different from most centers. Typically, centers evolve out of research projects pasted together, and they grow slowly. The NSF-sponsored centers are "big bang": They are created after much thought and attention by several higher-level university actors.

A second point is that all the centers we examined include truly excellent, internationally recognized researchers and are usually led by an eminent researcher. This means that the individuals involved generally have a good deal of social capital to spend on the centers, and they have considerable authority within the university.

Managing inter-university relations seems a much bigger challenge than managing intra-university relations. This is certainly understandable. In some cases, the researchers and administrators who are not acquainted are put together to strengthen a proposal—its scientific quality or fit—but also sometimes the coalition is based on geographic dispersion, diversity, or other non-technical factors. It is predictable that it would take some time for such relations to work well. When one also considers that multiple university (and sometimes state) bureaucracies have to be coordinated, the pitfalls seem apparent. And if managing faculty researchers is herding cats (as more than one center director observed), then managing faculty at multiple sites is an exercise in free-range feline herding.

The inter-university challenges are particularly daunting when they combine two academic cultures, such as engineering and medicine:

> There is a big cultural difference between engineering and medical schools. In a place like [my university], a department chair doesn't have as much authority. Another thing, the financial situation of medical schools has gotten worse recently, so finances are driven by the problem of indirect cost and "taxes" on professors' funding. Medical schools also have different relations to postdocs.

Another respondent addressed the possible problems of competition for funds among center affiliates at different universities. Part of the problem seems to be including too many partners in an effort to make proposals more attractive:

> We have competition [among researchers at affiliate universities]. Everyone at first thought we had more money than we actually had, and they all wanted more [to be allocated to them].... At first we had too many small projects trying to please everybody. Then we had to draw a line at minimum size budget. When [centers] were competing in 1986, the basic error we all made was we all had too many partners. Everyone knew about other [proposing university's] partners, and so it escalated.

While the NSF and the centers have worked out many structural and managerial issues of the centers, there is no easy mechanism for terminating ineffective partners.

> Can we get rid of partners? Not easily. They go away if they do not get as much funding as they expected, but it is amicable. They go away, but the [formal] tie with the center stays; they just go to other funding sources. The basic issue is that if you have one person at a university, then you claim that university as a core institution and then all of sudden you have five hands grabbing at the budget.

Despite understandable problems, inter-university relations can work well. One center director described the approach of his center, an approach he feels has been effective:

> With our university partners, we work more as a team. We have lots of people who have never worked together, but all buy into our visions and goals. We have an executive committee with five directors. The door is open to others to be involved also. We meet every month with new members the first year, every other month during year two. We get to know each other … develop trust and understanding. But this model does not work very well

> after a while. If we continue on this path, the whole program becomes an entitlement program, and we didn't want to continue that pattern.
>
> In the third year [of our relationship with a university partner], we fix an amount as a minimal budget for that school, with anything beyond that being dispensed on a merit and need basis. As our center budget grows, we freeze the baseline and everything beyond is distributed on a competitive [peer review] basis. This funding model has had an increasingly rigorous review process. We now bring in an external reviewer, then a relevant industry partner, and then us. We make the final decision. We map out the funding after that. We do give faculty a chance for rebuttal if they're rejected.

One center has developed a "road map" process to facilitate multi-university planning. It was described to us as follows:

> Our program is driven by our road map. It maps the fine details. The general center and every subgroup [research topic] area has a map. We have an annual retreat just to talk about and revise the road map. We have ten-year plans for all and also two-year plans in finer detail. Once the road map is defined, the direction is set. All faculty affiliated with the centers contribute.
>
> Once the road map is defined, the research proposals must adhere to the road map. If proposals deviate too far from the road map, I turn it down. I feel strongly that we have to do this. But with first- or second-year partners, we don't turn them down, because we want to build trust. We must gradually "change new partners" to our road map, because at the beginning there is uncertainty. But later we hold them to the road map. The road map is decided on by all. We choose our three best [in terms of research specialization] university partners to form a core. Funding is not the only issue here, but both funding and research direction. But we do not accept a dictatorial approach. That is one reason we have an annual retreat [to ensure a participative approach].

Our interviews led us to the conclusion that coordinating an MMURC's inter-university relations is a special challenge, and one that will not likely vanish even with the most effective of managers and management approaches. Organization theory gives us ample reason to respect the costs of coordination, and economic theory provides insight into shirking and principal-agent problems. But, of course, the returns from inter-university cooperation often are considerable. It permits the sharing of scarce and often extremely expensive equipment, and it provides incentives for disparate researchers from very different fields to work together. In many cases, the subsequent cross-fertilization is extremely important to the advancement of science and technology, and, of course, the MMURC as an institution largely stands or falls on its ability to promote such cross-fertilization.

Industrial Relations with MMURCs Can Change the University Culture

While there is not a huge literature on university research centers, industrial relations and technology transfer are the most common foci of the studies that have been performed (e.g., Behrens and Gray, 2001; Feller, 1997; Roessner, Ailes, Feller, and Parker, 1998; Betz, 1996; Santoro and Chakrabarti, 2001). To a large extent, those studies have been concerned with how university-industry partnership can lead to commercial effectiveness. In this section, our focus is more on the university center rather than on the partnership, and the interview data are from the universities (many previous studies consider data only from the university partners).

One point our study has in common with previous studies is the answer to the question, "What does industry want from relations with university centers?" According to much of the literature (e.g., Feller and Roessner, 1995), the industrial partners generally are not looking for fully developed technology that can be moved directly from the center to manufacturing and then product lines. Those few who are interested in such products are generally disappointed (Bozeman and Wittmer, 2001). Our interviews, and much of the literature, suggests that industrial affiliates are interested in working with and recruiting center students and helping with the training and currency of their own personnel; even when there is a strong interest in technology, they realize that they must do most of the development work. One center director captures the willingness of industry affiliates to live with uncertainty:

> Those that are interested in [the center's research specialty] often have no idea what they are going to do [with the knowledge we produce], but feel it is important for their future to keep an eye on what is going on. In the visit we had this week, the survey of affiliates, the number one answer was access to students. This is not so much [about intellectual property]. Our industrial partners get no intellectual property rights. They only get the priority to know, 60 days in advance of everybody else. But they seem to feel they get plenty out of the relationship.

Another center director underscored one of the major impacts of working with industry—more students taking jobs in industry: "I don't know if they [graduate students] are more likely to get a job by working with the center, but now 80 percent are going to industry. The ERCs have significantly enhanced students' interaction with industry, and this has opened doors and given [graduate students] familiarity with new places and possibilities."

Another topic of interest in the research literature is the influence of industry (e.g., Stahler and Tash, 1994; Cohen, Florida, Randazzese, and Walsh, 1998; Hicks and Hamilton, 1999), including the possibility for deleterious control of research agendas. If that is happening, then our interviewees have developed false consciousness. None, not even junior researchers, pointed to instances of industry exerting undue control. Apparently, industrial affiliates are somewhat influential in the MMURCs, but they do not generally "carry a big stick." One respondent described relationships thusly:

> Industry partners are made on a need basis. Their intention is never to direct us, but to influence us. So, they are involved in a "research review" by teleconference. We're "test bed" partners with 30 to 45 industrial members representing some 30 companies. They are closely involved. They exert influence on us, but never directly, just through this sort of interaction … as mentors in problem solving and planning general directions. We balance their input with our interests, but we put [our interests] number one. We've never had a conflict. Industry only advises; they do not dictate.

A continuing problem in some centers is inducing faculty researchers, especially younger, pre-tenure researchers, to invest time working with industry or doing research that has clear industrial implications. This is in large measure due to the fact that most academic departments, who control tenure and promotion for these faculty, provide little or no reward for industry work. One center's industrial liaison administrator, a doctoral-level scientist with previous industry experience, described the situation:

> It's getting better. I believe that having strong industry interaction in the area of sponsored research will spawn interest amongst faculty once the NSF money goes away. We have young faculty who aren't industry magnets, though that is changing. We have two new partners that are very impressed with [our younger faculty's] expertise. Part of my job is to say, "This is the science we have," and when they visit they realize we have a lot to offer. But we don't have many researchers with a lot of industry background. [Some of the junior faculty ignore industry and their needs]. That's just the name of the game. They have a lot of demands on their time. They also have less time to devote to our education and patent programs. So there's no incentive to spend time on these until after tenure.

It is important to note that not all centers are equally relevant to industry. For example, one of the centers we examined is working in a field where the research is still a long distance from commercialization and where the industry is still developing, with as yet no "big players." One respondent described a role that was more about keeping the possibility of developing an industry than about supporting a strong, existing industry:

> We do more basic research than some centers. This seems an appropriate investment for NSF … to help get this industry going. It's a better investment than one in an already established industry. The [industrial sector the center works in] is very complex. It's multidisciplinary: material science, cell therapy, gene engineering. There are very complex immune system issues to deal with … and then try to integrate into a product. These products are not manufactured easily. You need complex bioreactors and high-quality control. Then there's the regulatory affairs, which is another issue the NSF does not fully appreciate. The challenge is taking a combination of many [research] products and merging them into one. [Administrators] want to know milestones and when [to] achieve them … and with this loose regulatory process they get worried. Because these products are so revolutionary, they're going to have problems being picked up and paid for.… Other centers don't have to worry about this stuff. We have a number of challenges. It even trickles down to intellectual property. There's so much risk associated with these products.

While the conjoining of universities provides many benefits with respect to research, it often introduces complications with the transfer and commercialization of research. One industrial liaison describes his situation: "I deal with two technology transfer offices that have completely different philosophies on how to manage technology." One of the universities is best known for its medical school and has policies appropriate for promoting biomedical and pharmaceutical technologies. The other university is best known for engineering, and its technology transfer office is designed on a quite different basis.

In sum, our interviews suggested to us that fears about industry control do not seem to be borne out in these centers, but many of the problems of effective collaboration with industry remain. The problems of incentive structures and different university cultures loom large.

Conclusions and Recommendations

University research centers have managed to iron out many of the problems that emerged at their creation. For example, we have found that the centers' relationships with other units in the university are generally cordial and effective. Despite inherent competition between centers and academic units, administrators have found ways to emphasize common objectives in education and research. Though university administrators have succeeded in working through many early problems, others have proved less tractable. Most centers, especially ones funded by NSF, have enormous pressures for accountability and attendant bureaucratic requirements associated with such needs. Related to this, faculty researchers working at centers often have a nearly double administrative and committee meeting load, spending as much time as other faculty members with their academic department's business but, at the same time, preparing for center evaluation and site reviews, engaging in center outreach programs, and even dealing with diverse intellectual property requirements.

Obviously, academic researchers find it to their advantage to affiliate with centers—affiliation is not compulsory. Some affiliate because of the additional resources available, others because of the unique equipment, and still others because of the challenge of doing something new, something outside academic teaching and research routines. But as one Engineering Research Center director told us, "I have lots of carrots and no sticks." Center administration relies almost entirely on the power of persuasion. Tenure and promotion authority resides in the academic unit, often with crosscutting and even conflicting demands.

This lack of role congruence has been a problem since the beginning of the institutionalization of centers, and after 20 years it has been accommodated but has not diminished. The basic task for a center director remains assembling and organizing the right people with the right interests and expertise in a way that most effectively advances the science and technology at hand. The biggest challenge is doing this absent the full arsenal of managerial tools that chairs of academic departments and executives of industry enjoy. Our cases, discussed at length in previous sections, reveal numerous lessons that, if heeded, can help center directors compensate for this deficiency.

Recommendations for Center Directors and University Administrators

We have developed two different sets of recommendations. One set is for university officials, especially MMURC directors, but many recommendations are equally pertinent to university administrators who deal routinely with research centers. A second set of recommendations is for government program managers who either manage an MMURC or are considering establishing one.

- **Fit the reporting lines to the unique history and culture of the university.** There is no single rule about optimal reporting lines for MMURCs. While in theory one might assume that a large center should not report to a single dean or even department head but rather a provost or vice president for research, we learned that the success of reporting lines is better predicted by university history, strengths and weaknesses, and organizational culture than by apparent managerial rationality. For example, if the university's College of Engineering is high quality and one of the largest units on campus, then it might make sense to report to the dean rather than a provost. In such instances, nearly all the needed scientific and technical human capital may reside in the college, and the dean is likely to have sufficient power to help ensure effective administrative linkages to the center. Indeed, in one case we examined, a very effective organization reporting scheme had developed with an MMURC reporting to the head of a large department. This scheme had the advantage of aligning the center's and the department's expectations about tenure and promotion.

We do *not* suggest that reporting lines be built on personal histories. While it is certainly the case that a center may benefit, at least in the short run, from building reporting lines on strong interpersonal relationships, doing so makes the center hostage to the vagaries of individual careers.

- **Have center directors focus on research administration and linkages; administrative directors should be empowered to make routine internal management decisions.** The smoothest running MMURCs are those where there is clear specialization of managerial tasks between the center director and the administrative director, with the former addressing primarily issues related to research direction and the procurement of funds and the latter focusing on tasks that do not require scientific knowledge and expertise, such as NSF reporting requirements and logistics for events like workshops and conferences. In some cases, directors also have considerable skill in linkages with other universities and industry as well as intra-university linkages. In almost every instance, our analysis indicated that the administrative director is a key figure and that the center's effectiveness depends to a substantial degree upon having a competent person in that position.
- **Consider hiring a research management generalist.** Hiring a research management expert—someone with a Master of Business Administration or comparable degree, and perhaps industry R&D management experience—can facilitate interdisciplinary research activity. When an administrator is dedicated to the coordination of scientists from disparate fields, there is a stronger likelihood that emergent problems will be quickly recognized and steps will be taken to remedy such problems. Though this administrator need not have a technical background, he or she must have a willingness to learn the fundamental approaches and objectives of research. More than most center personnel, a research general manager must have the confidence of the center director and the research team directors and must be viewed as a facilitator rather than a supervisor.
- **Set aside a small percentage of center funds as seed grant money for underdeveloped yet promising research proposals, as a way to diffuse competition over center funds.** Generally, the most difficult decision center directors face is which project to support. Few make these decisions unilaterally and, instead, depend on research team leaders, an executive committee, and/or an advisory board to help make such decisions. But it is generally not a good idea for the center director to retreat too far from making hard decisions about resource allocation. If there is no central decision making, then it is difficult to develop a center research niche or a strategic research portfolio. One of the ways to develop a strategic approach to research but, at the same time, mitigate conflict is to have a set-aside for competitive award, perhaps complete with peer review. This provides an outlet for those who do not have their project endorsed by the center strategic plan or by decision authorities. It is also a good way to ensure that center portfolios at the same time evolve and have some central thrusts.
- **Nurture collaboration among center members with regular meetings and multiple avenues of communication.** In multi-institutional collaborations (an attribute of MMURCs), it is easy enough for participating institutions to become absorbed by local concerns, with the result that

the joint concerns of the collaboration do not receive ample attention. As we found in our analysis, many center directors are well aware of this possibility and forestall it by regular review of current projects, scheduled multi-institution workshops, and frequent informal communication. The key, of course, is to respect the time of participants and to ensure that meetings and other communications forums are goal directed and perceived as open and mutually beneficial.

- **Cultivate industry partners interested in long-range relations and pre-commercial science and technology.** Sometimes the most eager industrial affiliates make poor partners. Some firms have an unrealistic view of university research centers (sometimes due to unrealistic university promotion of centers) and expect that centers are reservoirs of developed technology merely awaiting commercialization. Generally, the best industrial partners are those who are interested in: (1) applied science that they can take to the next stage of development, (2) staying current with the latest developments in the field, with or without specific commercial objectives, and (3) working with the centers as potential employees for industry—for example, students and postdoctoral candidates.

Recommendations for Government Program Managers

While some of our recommendations for government program managers pertain to those with existing MMURCs, others are directed to those who are trying to determine if this is a useful organizational design to achieve their program's research objectives.

- **Live (or die) with the university culture.** Despite the fact that research universities have changed enormously during the past few decades, it is important to recognize that they are not government labs or industrial consultants. While many universities have become quite adept at performing applied research missions with great effectiveness, a government program manager should not expect, or even desire, the level of compliance and responsiveness one often receives from industry contractors or federal laboratories. The comparative advantages of the university setting include: (1) the ability to do truly cutting-edge research; (2) the availability of students and postdoctoral researchers; and (3) a large reservoir of diverse scientific and technical talent. But the university almost always carries liabilities, including: (1) it is prisoner to the academic calendar, and faculty and students must tend to educational needs; (2) the reward systems for research are generally discipline based and oriented to refereed publications (rather than to a diversity of scientific and technical outputs); (3) faculty researchers are particularly impatient with administrative and accountability procedures; and (4) faculty researchers have their own research agendas and are not easily deflected from them.

  Insofar as the research objectives of the government manager are dependent upon the strengths of universities and can at least tolerate the apparent weaknesses, the *MMURC* may prove preferable to an industry or government laboratory performer. But government managers should expect to influence, at best, only incremental changes in the university culture, even in the MMURC.

- **Determine whether an MMURC or a more traditional university research center is the right fit.** Read the label. Not all university research centers are MMURCs. In many instances, the government program manager may find it useful to work with, or cultivate, a traditional university research center. The term *MMURC* encompasses "multidiscipline" and "multi-institutional." For some problems, a multidisciplinary focus and the resources of multiple institutions are exactly what are required. But the power of the "multi's" comes at a considerable cost. Even when center partners work well together, it is always more costly, and generally riskier, to work with a multi-institutional center than a single institution. Effective coordination is almost never achieved cheaply. By the same token, bringing together many disciplines on a scientific or technical problem, while certainly seeming like a good idea, is almost always more difficult than bringing together people from a single discipline. If scientists are from a single discipline, then they are much more likely to share work norms and aspirations, to understand one another, to respond to shared incentives, and to have a shared concept of quality. In sum, multidiscipline and multi-institutional may be exactly what is needed, but program managers must be aware of the downside risk.

- **Strive to minimize double duty.** The template for (arguably) the original MMURC, the NSF Engineering Research Centers, stipulated that the centers' full-time researchers would be faculty affiliated with departments. There is much wisdom to this decision. In most universities, for good or ill, those who are not tenure-track faculty are second-class citizens. Second, the stipulation ensures that competition with academic departments will at least be among friends rather than strangers. But a great disadvantage to this arrangement is that center researchers have two jobs. Affiliation with an MMURC does not reduce the commitment to committee meetings, it expands it; it does not limit the time mentoring students, it increases it; it does not simplify the research and technology portfolio, it makes it more complex. Many of the faculty researchers we interviewed lived two interesting lives—one as a traditional academic, teaching and publishing in the discipline's refereed journals, and another working on the center's applied research and technology problems, perhaps working with industry groups and fitting into research teams composed of persons from a variety of disciplines and sometimes remote institutions. The chief point is that government (and center) managers must recognize the dual life and set expectations accordingly. Center researchers are "jugglers" with many balls in the air, and the price of the current organizational design is that some of those balls will occasionally come crashing down.

- **Provide distinct management guidelines for centers, identifying potential pitfalls as well as responsibilities.** Government program managers should revisit and, if necessary, update these guidelines on a regular basis or whenever there is an apparent impasse between the program manager and a center. When mutually beneficial, it is important to allow for exceptions to these guidelines. One useful approach is the managerial template that the NSF Engineering Research Centers Program has provided. While not all ERCs find this level of detail helpful, some do, especially at the startup point. Generally, guidelines are a better approach than extended requirements. The level of accountability reporting at most MMURCs is considerable, often requiring a staff person dedicated fully to the task. In many instances, government managers have no ability to reduce the reporting load, but by being constantly mindful, they can at least ensure that they are not contributing unnecessarily.

- **Find the right culprit.** All university research centers have their unique approach to management, but they are also embedded in a larger university administrative context and, sometimes, a state government context. It is often difficult for government program managers to know where to attack problems. Sometimes efficiency or effectiveness barriers are at the level of the center, sometimes the university administration, sometimes the state government, and, all too often, some interaction among them. These problems are compounded when the center includes many universities with their own distinctive management cultures. This is more a warning than a recommendation—program managers need to be patient in getting to the bottom of problems. The fact that most interaction will be with the center director and staff does not mean they are necessarily at the root of a performance problem, and, indeed, the center staff and the government program manager may be "on the same team" and mutually helpful in addressing problems that originate elsewhere.

- **Do not encourage "shell collaborators."** There is a tendency among those proposing centers to assume that more collaborators equal a stronger chance of approval. There seems to be some merit to this view; a reading of both funding history and submission guidelines for some centers' programs might well lead one to that conclusion. In some instances, there may be political forces that dictate "more is better," forces over which the government manager has no control. But in other cases, government managers do well to bring skepticism to claims of collaboration. In the cases we analyzed here and elsewhere, we concluded that most collaborations are valid and effective, but some are entirely window dressing. Shell collaborations consume vital resources with limited return. In most instances, government program managers will not be able to easily determine when collaborations will be viable (indeed, the center collaborative partners cannot be confident that collaborations will be effective). The key, then, is to scrupulously evaluate not just the centers but also the quality of the collaborations. While this cannot usually be accomplished in year one, by year two or three a collaboration that is not effective is not likely to become effective. It is at this point that program managers need to be active in center triage.

In light of the fact that so many of our recommendations seem cautionary, it is important for us to underscore that the MMURC is, despite the potential difficulties in management and design, one of the most important institutional innovations in (at least) the past 30 years. Both the scientific and management challenges of MMURCs are prodigious. But the possibilities for accomplishment are stunning. The MMURC has the potential to harness the historical advantages of university research and at the same time transform university research into a mechanism for solving a broader and deeper array of scientific, technical, and social problems. In previous years, the expectation was that universities would produce vital knowledge, with little expectation that they would play a role in making the knowledge immediately useful or in linking with industry to accelerate the process of translating knowledge into economic and social solutions. The MMURC has helped to do just that. The fact that the institution continues to have growing pains certainly does not diminish its beneficial catalytic role.

Appendix I: Criteria for Engineering Research Center Awards

Primary Criteria

What is the intellectual merit of the proposed activity?

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project?…

What are the broader impacts of the proposed activity?

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?…

Basis for Determining Above Criteria

Integration of Research and Education

One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students, and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

Integrating Diversity into NSF Programs, Projects, and Activities

Broadening opportunities and enabling the participation of all citizens—women and men, underrepresented minorities, and persons with disabilities—is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

Additional Review Criteria

- Proposal defines an emerging engineered system with strong potential to spawn new industries, transform our current industrial base, service delivery system or infrastructure, and have a broad societal impact.
- Research plan targets critical systems goals, identifies challenging scientific and technical barriers to be overcome, and proposes research projects and proof-of-concept test beds to address these barriers.
- Proposal demonstrates a clear knowledge of the state-of-knowledge and the state-of-the-art and presents a persuasive strategy for advancing them.
- Education plan integrates the ERC's research activities and results into curricula at all levels, achieves a team-based, cross-disciplinary culture

for undergraduate and graduate students, and incorporates effective plans for implementation, assessment, and dissemination of curricular materials.

- Outreach will expose a broad spectrum of faculty, teachers, and students to the ERC's research culture, impact pre-college curricula, and motivate students to study engineering.
- Proposal provides a convincing rationale for the selection of industrial/user partners and engages these partners in planning, research, education, and technology transfer.
- Institutional configuration is appropriate to the goals of the ERC and, for multi-university ERCs, collaboration is integrated across the participating universities.
- ERC has expertise in all disciplines required to attain its goals, a capable leadership team, and leadership, faculty, and student teams diverse in gender, race, and ethnicity.
- Organizational structure and management plan effectively organize and integrate the resources of the ERC to achieve its goals and include strong advisory and project selection/evaluation systems. In a multi-university proposal, the resources of all institutions must be effectively integrated.
- Experimental, computational, and other required equipment, facilities, and laboratory space are in place or proposed to support the research of the Center.
- The participating institutions have committed to encourage, support, and facilitate the dissemination of the interdisciplinary research, educational, and diversity programs of the ERC.

Criteria for Full Proposals Only

- Headquarters space proposed for the Center will effectively encourage and facilitate interdisciplinary collaboration and house the management functions of the ERC.
- Commitments from firms to be fee-paying members of the ERC, if an award is made.
- Proposed terms of the industrial membership agreement will structure a center-wide program of industrial collaboration to support overall ERC goals, as opposed to a collection of individual sponsored projects; proposed terms of the intellectual property policy will facilitate technology transfer.

Source: http://www.nsf.gov/pubs/2002/nsf0224/nsf0224.htm#REVIEW

Appendix II: The Contours of Academic Research in the U.S.

There are excellent sources of information about university research. Excellent book-length treatments are available on the history of university research and its current and future importance. Indeed, there is of late an emerging cottage industry of books written by former presidents of elite universities (Rhodes, 2000; Duderstadt, 2000; Kerr, 2001; Bok, 2003). Abundant statistics have been compiled by the National Science Foundation and are available online (www.nsf.gov). While we have no desire to compete with the abundant general information available about university research and its organization, some introductory context would perhaps be useful.

Perhaps the first point to understand about U.S. colleges and universities is their profusion. There are more than 3,900 U.S. colleges and universities, more than six times the number of Japanese universities, and more than eight times the number of French colleges and universities. In Great Britain, still one of the leaders in basic science publications, there are only 88 universities. (Before the 1982 upgrading of British polytechnics to full university status, there were 45.)

The number of universities is not the best indicator of the university research role. Most of the U.S. university research output (i.e., scientific papers, journal articles, books, patents, licenses) comes from less than 10 percent of the more than 3,900 colleges and universities. For several years, the Carnegie Institution has provided a classification scheme for U.S. universities. While the scheme is based on degrees granted (type and number), it is also quite useful for analysis of research funding.

The Carnegie categories include:

Doctoral/Research Universities—Extensive
Doctoral/Research Universities—Intensive
Master's Colleges and Universities I
Master's Colleges and Universities II
Baccalaureate Colleges—Liberal Arts
Baccalaureate Colleges—General
Baccalaureate/Associate's Colleges

While our present concerns require no detailed description of the categories, the basic distinctions are obvious from their names: Some produce only baccalaureate degree holders, some also produce master's degree holders, and some produce doctoral degree holders. Many extremely competitive institutions have no graduate programs and are chiefly engaged in the education of undergraduates and, generally, have quite modest research activities. From the standpoint of contributing to the U.S. national innovation system, the 261 doctoral universities—only 7 percent of the total—are by far the most significant producers of research. Table A.1 (see page 44) gives the distribution of colleges and universities by type. As we see, fully 42 percent of the 3,941 are two-year colleges where there is little or no research mission (http://www.carnegiefoundation.org/Classification/CIHE2000/Tables.htm, downloaded June 2, 2003). To be sure, the universities that do not have doctoral programs or significant research missions nonetheless have an extremely important role to play in the U.S. research enterprise. A great many of the students pursuing doctoral degrees have undergraduate training from universities that do not grant doctoral degrees.

Table A.1: Distribution of Higher Education Institutions by 2000 Carnegie Classification

Category	Number of Institutions	Percentage Distribution
Total	3,941	100.0
Doctoral/Research Universities	*261*	*6.6*
Doctoral/Research Universities—Extensive	151	3.8
Doctoral/Research Universities—Intensive	110	2.8
Master's Colleges and Universities	*611*	*15.5*
Master's Colleges and Universities I	496	12.6
Master's Colleges and Universities II	115	2.9
Baccalaureate Colleges	*606*	*15.4*
Baccalaureate Colleges—Liberal Arts	228	5.8
Baccalaureate Colleges—General	321	8.1
Baccalaureate/Associate's Colleges	57	1.4
Associate's Colleges	1,669	42.3
Specialized Institutions	*766*	*19.4*
Theological seminaries and other specialized faith-related institutions	312	7.9
Medical schools and medical centers	54	1.4
Other separate health profession schools	97	2.5
Schools of engineering and technology	66	1.7
Schools of business and management	49	1.2
Schools of art, music, and design	87	2.2
Schools of law	25	0.6
Teachers colleges	6	0.2
Other specialized institutions	70	1.8
Tribal Colleges and Universities	28	0.7

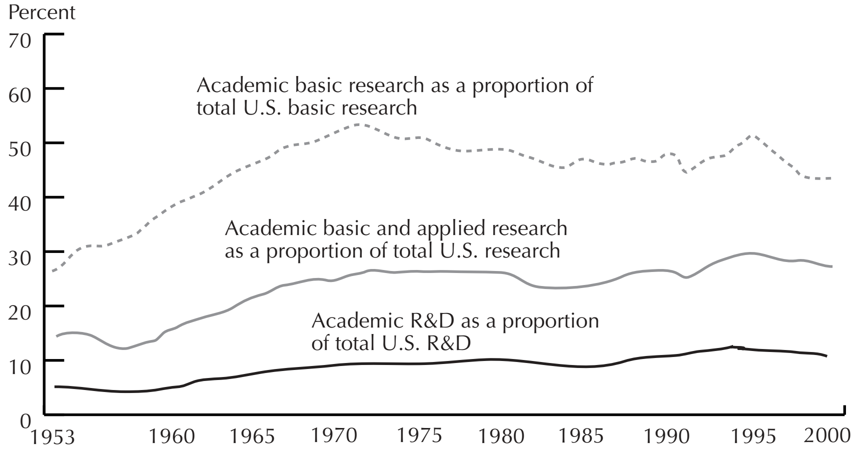
Notes: Figures in italics are aggregated from subcategories. Percentage details may not sum to totals due to rounding.
Source: http://www.carnegiefoundation.org/Classification/CIHE2000/Tables.htm

If we consider the amount of money spent on R&D, we see that the university sector has played an increasingly prominent role. As we can see from Figure A.1, universities provided only 11 percent of total U.S. R&D in 2000, but an estimated 27 percent of the applied and basic research in 2000, including 43 percent of basic research. For some time, universities have been the major provider of basic research. Over all, industry remains the greatest provider of R&D, but industry invests a great deal in technology development and relatively little in basic research. The share of academic research, as a percentage of all providers, has doubled since the 1950s, from about 14 percent to 30 percent. As a proportion of gross domestic product (GDP), academic R&D rose from 0.07 to 0.30 percent between 1953 and 2000 (National Science Board, 2002).

Figure A.2 reinforces the point that academic research is an elite enterprise. As Figure A.2 shows, the top 100 universities spent about one half of the $30 billion that the 3,900 U.S. colleges and universities spent on research in 2000. Where do these research dollars come from? As Figure A.3 shows, the federal government is, by far, the chief provider of academic research funds.

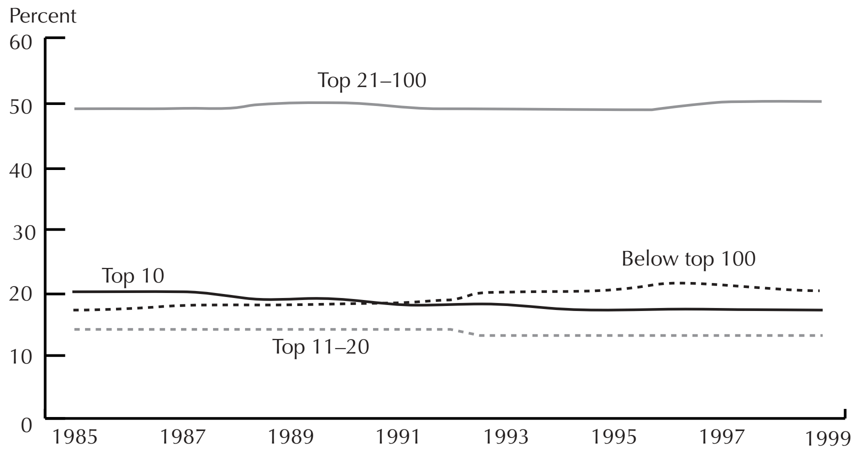
From the standpoint of understanding university research centers and their importance, these con-

Figure A.1: Academic R&D, Basic and Applied Research, and Basic Research as a Proportion of U.S. Totals: 1953–2000



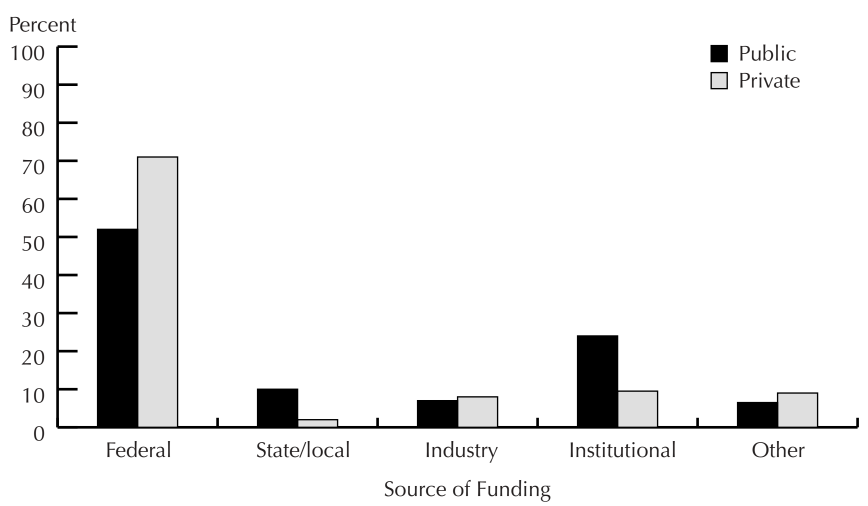
Note: Data for 1999 and 2000 are preliminary.
Science & Engineering Indicators–2002

Figure A.2: Share of Academic R&D of Universities and Colleges by Rank of R&D Expenditures: 1985–1999



Science & Engineering Indicators–2002

Figure A.3: Sources of Academic R&D Funding for Public and Private Institutions: 1999



Science & Engineering Indicators–2002

textual features of academic research are especially important:

- Just as the research funds are heavily concentrated in the doctoral-granting universities, so are the centers.
- Universities are strongly oriented to basic research, and many of the university centers represent efforts to balance, diversify, or integrate research types, especially encouraging increased applied research.
- Just as the federal government is the chief source bankrolling university research, it is also the chief source of funding for university centers—this despite the focus of centers on increasing industry support of university research.

Endnotes

1. http://www.instadv.ucsb.edu/news/hot-news/00-01/20001207a.htm, downloaded August 18, 2003.

2. Personal interview with the authors, May 23, 2003, Washington, D.C.

3. This is a preliminary estimate based on Georgia Tech's Research Value Mapping Program's pre-test survey of 443 university science and engineering faculty implemented in fall, 2002.

4. With the exception of a few public officials, we do not identify particular individuals in the interview data presented below. The Center-affiliated interviewees are all from the list of MMURC interview sites listed in the appendix, including both NSF ERCs and STCs. While we made no promise that the interviews would not be for attribution, and no such pledges were asked of us, there seems to us little to be gained by identifying particular individuals.

5. Personal interview with Dr. Lynn Preston, Deputy Division Director, Division of Engineering Education and Centers and Leader of the ERC Program, National Science Foundation, March 11, 2003.

6. According to the NSF, "a cooperative agreement is a type of assistance award which may be used when the project being supported requires substantial agency involvement during the project performance period. Substantial agency involvement may be necessary when an activity: is technically or managerially complex; requires extensive or close coordination with other Federally supported work; or helps assure suitability or acceptability of certain aspects of the supported activity. Examples of projects which might be suitable for cooperative agreements are systemic reform efforts, research centers, policy studies, large curriculum projects, multi-user facilities, projects which involve complex subcontracting, construction or operations of major in-house university facilities and major instrumentation development." http://www.nsf.gov/bfa/cpo/gpm95/ch2.htm#ch2-2, downloaded August 9, 2003.

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