Part I

Conclusions

Chapter 1
Background

We have a simple message: To ensure their institution's commitment to excellence in mathematics research, doctoral departments must pursue excellence in their instructional programs.

Most reports about resources for mathematics research have focused on federal funding. This book is different in that it focuses on the health of universities and especially on the health of doctoral mathematics departments. Despite the substantial support that is provided by federal granting agencies, far greater support for mathematics research is provided by America's colleges and universities. Foremost among them are the research universities, whose support includes the employment of both faculty with a substantial research mission and large numbers of graduate students who teach while pursuing a doctoral degree.

This approach—investing in research through America's colleges and universities—has led to enormous achievements both in education and in mathematics research. The past five decades have been a particularly successful period for American mathematics, with increasing enrollments and public support fueling striking advances in mathematics research.

But higher education in the United States is facing challenges on every front. Faculty are asked to reform teaching and to be accountable for student learning. At the same time, they are still expected to advance research frontiers and retain preeminence in the creation of knowledge. They are also asked to assume new roles in K–12 education and social programs. A fiscally conservative national climate and downsizing ethic in the 1990s has cut budgets for education, especially at the college level, along with most social programs. Universities across America face staggering financial problems, forcing them to make difficult decisions about competing priorities. At the same time, there has been an erosion of public confidence in higher education and public respect for research scientists.

Mathematics departments throughout the nation are especially feeling the strain. They are besieged by requests to reform the teaching of courses that affect almost all students in universities. Doctoral departments must nurture research programs in an increasingly competitive environment. The 1995 CBMS enrollment survey reported a substantial drop in mathematics enrollments for the first time in the survey's history. Mathematicians face a bewildering array of desires, demands, and criticisms.

Given these challenges, it is remarkable that the mathematics profession has responded to the degree that it has in the last few years. While there are many problems, there are also many successes. Building on these successes, this resource book tries to assist doctoral mathematics departments in assessing their changing environment and prospering within it. Our aim is not to criticize but to elucidate.

Task Force History

In November 1991, the Council of the American Mathematical Society charged the AMS Committee on Science Policy (CSP) to develop a science policy strategy that was consistent with the Society's mission and that addressed the issues faced by the research community. The resulting report from CSP contained these passages:

> U.S. universities and their mathematics departments share an increasing responsibility to the society in which they exist. This responsibility is met primarily by a strong commitment to quality teaching and the advancement of knowledge within the discipline, but increasingly extends to outreach activities that include the preparation of teachers, the encouragement of youth, community service, and a special obligation to encourage women and minorities to be successful in mathematics.
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> The CSP urges the AMS to take a leadership role in the profession in advocating a rich understanding of the challenges and obligations that face our profession, especially those who teach and engage in research in our universities. While the leading model for faculty is teacher-scholar with a strong commitment to both the creation and transmission of knowledge, the AMS should promote respect for and proper rewards to those who help meet a department's total mission through focused effort in teaching, research, or outreach activities.
>
> The CSP advocates increased attention by departments to educational reform and revitalization of the mathematics curriculum, as well as to activities that encourage and nurture undergraduate students, including increasing their understanding and appreciation of mathematical research and the connections of mathematics to other disciplines and to society's needs.

Among the recommendations that the CSP made to the Society was the following:

> In order to help departments meet the broader range of responsibilities advocated by the AMS, the CSP recommends that the AMS take an active role in support of mathematics departments, with a special emphasis on supporting the needs of Ph.D. granting departments, by helping departments make the case for adequate resources from their colleges and universities. The CSP makes the following recommendations designed to support mathematics departments and the chairs who lead their departments:
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> . . .The CSP supports the formation of a Task Force on Resource Needs for Excellence in Mathematics Instruction as proposed by the Long Range Planning Committee.

The full CSP report can be found in the November 1992 issue of the *Notices* of the AMS.

In 1992 AMS President Mike Artin appointed the ad hoc Committee on Resource Needs for Excellence in Mathematics Instruction and gave it an ambitious charge to:

- Identify the operational issues affecting doctoral-granting mathematical sciences departments.
- Conduct an analysis of the available information on these issues.
- Articulate the role of the mathematical sciences within academe and the mission of the university.
- Make recommendations on the resources needed by doctoral departments for excellence in mathematics instruction.
- Produce a cogent report for use by mathematical sciences departments and university administrations in planning and allocating resources.

Our committee got off to a slow start, in part because of the resignation of our first chair and in part because our activities were limited by a lack of resources. In late 1993 Mort Lowengrub, Dean of the College of Arts and Sciences at Indiana University, agreed to become chair of the committee. Under Lowengrub's leadership the name of the committee was changed to the AMS Task Force on Excellence in Mathematics Scholarship: Assuring Quality Undergraduate and Graduate Programs at Doctoral Granting Institutions.

The work of the Task Force increased pace in 1994 when we received partial funding from the Exxon Education Foundation, and again in 1995 when we received funding from the National Science Foundation. The support of these two Foundations is gratefully acknowledged.

Starting in August 1994 and extending through November of 1996, the Task Force held a series of 14 focus group discussions to identify the critical issues facing departments of mathematics at Ph.D.-granting institutions, as well as to gain insight into the many ways that departments are responding to the issues they face. Most of the focus group discussions (9) were held with chairs of mathematics departments at Ph.D. institutions. Other discussions were held with college deans (3), Project NExT Fellows, and department chairs at institutions that do not award the Ph.D. degree. Many readers may find the summaries of the focus group discussions the most valuable part of this book.

During the 1996–97 academic year, the Task Force also made five site visits to departments that had repeatedly been mentioned as being successful in both research and various aspects of their instructional program. The reports of those visits in Part III are not meant to hold these departments up as models, nor is there any attempt to discover any weaknesses they may have. Rather, they describe some successful practices that may suggest effective strategies for other mathematics departments.

Task Force Goals

Initially, the focus of our Task Force was helping a mathematics department make the case to get the dean to support the mathematics department better. Indeed, many chairs hoped the Task Force could produce a one-page fact sheet with information about similar mathematics departments that could help them persuade their dean to provide more support for their department.

Unfortunately, the message coming from many department chairs was that their deans were very unsympathetic to giving resources to their departments despite rising enrollments. Many chairs felt deans treated their mathematics department as a "cash cow", teaching large numbers of students at a low per-student cost. It soon became clear that convincing a dean to provide needed resources required a mutual understanding between the dean and the department of the mission of today's mathematics department and how that mission fits in with the overall mission of its university.

The goals of the Task Force expanded as we drew up a list of critical issues that departments needed to address; for example, developing strategies for implementing recommendations from recent national reports. While the work of the Task Force continued to reflect its original focus, we also saw its mission expanding.

Eventually, we recognized that our goals had become so ambitious that effectively accomplishing them all was not realistic. Our work then began to focus on a narrower set of core issues and recommendations, which were guided by an appreciation of the remarkable variety of doctoral departments. One central finding that impacted most of our Task Force's agenda was: A key to protecting and strengthening a doctoral mathematics department and its research programs is to pay proper attention to the instructional side of the department's mission. Consequently, one objective of this book is to convince research departments that they should value quality instruction not just because of its importance to the mission of the university, but also because of its importance to the overall health of a research mathematics department.

There is one potential topic that we did not address at any time: offering suggestions to departments about how to improve their research programs. Some may view this as strange for an organization that represents research mathematicians. There are reasons for this omission. First, several highly qualified panels have recently addressed this issue (see the National Research Council's "Renewing U.S. Mathematics: A Plan for the 1990's", 1991, and "Renewing the Promise: Research-Intensive Universities and the Nation", 1992, issued by the President's Council of Advisors on Science and Technology). Also, many chairs told the Task Force that deans today are unresponsive to appeals for resources that are based primarily on the need to enhance research excellence. Thus, while resources for research and doctoral training were always on the Task Force's mind, we came to believe that greater attention to high-quality instruction is the critical issue today for sustaining and enhancing high-quality research.

Why Doctoral Departments?

There are several reasons for our focus on doctorate-granting mathematics departments. First, doctoral departments produce most of our future mathematicians and much of our mathematics research. The health of these departments is important to the overall health of American mathematics. How new faculty educated in these departments view their professional responsibilities impacts all of higher education.

Second, there are a number of ways in which the instructional environment in a typical doctoral mathematics department is different from that of a department whose highest degree granted is either a bachelor's or master's degree. The most obvious ways include the heavy focus of the department on research and doctoral education. Such departments are far more likely to rely heavily on the use of graduate students as teachers (or teaching assistants). They also are more likely to rely on a large lecture format as a means of teaching large numbers of freshman and sophomores.

Third, research universities now stand accused of failing to do an adequate job (much less an outstanding job) of educating undergraduates. More broadly, large portions of society question whether universities, and especially research universities, are meeting the needs of society. The Mathematical Sciences Education Board's "Report of the Task Force on Teaching Growth and Effectiveness" argues that universities must do a better job of explaining—to themselves and to the public—exactly what it is they contribute to society. It further says that "faculty need to demonstrate the effectiveness of their educational work."

A much stronger indictment of research universities comes from the 1998 Carnegie Foundation report of the Boyer Commission, "Reinventing Undergraduate Education: A Blueprint for America's Research Universities". The report says, "Universities are guilty of an advertising practice they would condemn in the commercial world. Recruitment materials display proudly the world-famous professors, the splendid facilities and the ground-breaking research that goes on within them, but thousands of students graduate without ever seeing the world-famous professors or tasting genuine research."

It would be easy enough to reject such criticism as unfair, to state unequivocally that our Task Force believes that most doctoral mathematics departments are already doing a good job in teaching undergraduates. A premise of this book is that it is a much wiser idea to take a clear look at ourselves, taking stock of our strengths and identifying weaknesses that need to be addressed.

Increasingly, doctoral mathematics departments (and many departments in other disciplines) are challenged to defend their programs and to "do more with less". It is at least popular wisdom that departments and universities are in a time of change that is more rapid and significant than any of us have seen over the past thirty years. All too often, department leaders find themselves unprepared for many of the challenges they face. In large part, it was this quandary that led the AMS Long Range Planning Committee and the Committee on Science Policy to recommend that the AMS establish this Task Force to help departments with these problems.

All mathematics departments in this country share many concerns and aspirations, but they also have differences. The work of our Task Force was directed largely at the particular burdens and responsibilities of doctoral-granting mathematics departments.

All of our work assumes the centrality of research in the mission of doctoral mathematics departments and assumes that research and education are essential to one another. In most doctoral departments there is a clear vision for research excellence. While some departments may be struggling to achieve that vision, most have a clear understanding of a plan for doing so. There is therefore no attempt here to consider how to directly enhance the research life of a department, or to improve the research faculty, or to expand (or contract) research areas. Here too, departments differ greatly, and there are no easy answers to complicated problems.

At one time we hoped to make definitive suggestions as to how to respond to all of the critical issues facing doctoral departments. This was far too ambitious. While the information in this book can help a department determine how it wishes to respond to the variety of reform efforts that have been issued, the Task Force does not presume that there is one set of recommendations about institutional mission and instructional excellence that every mathematics department can use.

Even when focusing on doctoral departments, the differences between private and public institutions and between those at the levels the AMS refers to as Groups I, II, and III are often significant. (See Appendix B for a list of universities in these groups.) The differences between mathematics and applied mathematics departments are even more significant as, for example, in the distribution of instructional workload among graduate, upper-division, and lower-division courses. However, our concern for understanding the mission of one's institution and responding to it appropriately is important to all departments. It speaks to the differences in departments. Attention to this concern helps every department look at this book in the right way.

Chapter 2
The Environment in Which We Work

One of the most important responsibilities of a department's leadership is to position the department to receive at least its fair share of the resources available to the university. In order to meet this responsibility, it is first necessary to understand the environment in which the department and the university operate.

For background, a brief summary of changes in this environment over the past fifty years is helpful. The second half of the twentieth century has been a golden age for academic research in the United States. Many of today's academic leaders entered the professoriate when universities and colleges were fully funded and growing rapidly and doctoral programs were multiplying. Initially, mathematics departments were beneficiaries of cold war policies that put a premium on engineering and other mathematically based disciplines. Later the growing importance of quantitative reasoning throughout science and business kept mathematics enrollments growing. In the 1968 National Academy of Sciences report of the Committee on Support of Research in the Mathematical Sciences, demand for new mathematics Ph.D.'s was projected to grow to 2,000 per year in 1972 and eventually to 3,000 per year.

This emphasis on research and graduate education did not exist in the first half of the century, when most universities had an undergraduate teaching orientation and many of their mathematics faculty lacked a Ph.D. Beginning in the 1960s, university faculty became more focused on research and doctoral training. Even presidents of four-year colleges wanted their faculty to be publishing research papers, along with teaching 12 hours a week. University of California president Clark Kerr built up the UC universities beginning in the 1950s with the widely copied strategy of recruiting top research faculty with reduced teaching loads and high salaries. Before long, only research mattered in promotion and salary decisions. Today, after a sustained period of shrinking budgets during the first half of the 1990s, leaders in higher education are struggling to find an appropriate balance between research and teaching.

At a panel at the AMS 1993 annual meeting, William Kirwan, then president of the University of Maryland at College Park and now president of The Ohio State University, suggested an appropriate title for this Task Force might be "How Do Mathematics Departments Survive during a Time of Diminishing Resources and Declining Public Support?" He went on to say that universities "have needs and demands for expanded activities that far outstrip available resources," and "the only thing falling faster than our resource base is public understanding of and support for the work we do at research universities."

President Kirwan went on to say that the lack of attention given to undergraduate education is the cause of much of the criticism of research universities and quoted Derek Bok, president emeritus at Harvard, as saying the lack of attention to undergraduate education, primarily at research universities, was the number one issue causing the decline in public trust of higher education. He also quoted the following warning from Richard Atkinson, President of the University of California System, "... research universities should lead the way by restoring the balance between teaching and [research] ... the continued greatness of the American research university depends on ... an equilibrium between the three missions of its charter ... the propagation, creation and application of knowledge. When the balance goes awry, the entire edifice erodes."

More recently, in 1997, the Council for Aid to Education released a report titled "Breaking the Social Contract: The Fiscal Crisis in Higher Education", in which they wrote, "Our central finding is that the present course of higher education --- in which costs and demand are rising much faster than funding --- is unsustainable." In an open letter to faculty, the president of one public university recently identified three trends in his state:

- annual decreases in the proportion of the state budget allocated to the university,
- increases in tuition limited approximately to the rate of inflation,
- an ever increasing percentage of the operating budget absorbed by salaries.

It is encouraging to note that in the fall of 1998 many state universities reported significant increases in enrollment, and some private universities are reporting an increase in the quality of their applicants. Still, some version of the trends reported above are likely present in most states. As states struggle to fund other priorities (health care, K–12 education, prisons) and respond to various forms of taxpayer revolts, support for higher education becomes a lower priority. Private universities face a different set of problems, but they too find themselves unable to turn to traditional sources of income, such as tuition increases, to meet their need for increased revenue.

Thus, higher education, and especially research universities, face both a resource problem and a problem centered on the concerns of many that we are not meeting the needs of society. University administrators are increasingly responding to their resource problems by making hard choices as to which programs will continue to receive the support necessary to pursue excellence and which will find their support reduced significantly. University administrators are also responding to the criticism they hear by pledging greater attention to undergraduate education and the needs of the communities which support them. Mathematics departments and their leaders would be wise to pay attention to these trends.

One national initiative is trying to blend a commitment to undergraduate education with a partnership with K–12 education. Called the “P–16 Initiative”, it has the strong support of The Education Trust and the National Association of System Heads. In eighteen states both the state commissioner of education and the president of the state’s higher education system have formed a partnership to create a “seamless” education system from (pre)kindergarten to the bachelor’s degree (i.e., grade 16). This is a standards-based initiative that places an emphasis on aligning state standards for high school graduation with college entrance requirements and also places a new emphasis on teacher preparation.

The National Science Foundation has thrown its support behind its report “Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology”. This report, authored by Mel George, professor emeritus of mathematics at the University of Missouri-Columbus and president emeritus of St. Olaf College, sets forth one overriding goal: All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students learn these subjects by direct experience with the methods and processes of inquiry.

Taking Stock

Assume for a moment that you are the chair of a doctoral mathematics department and you plan to meet with your dean to discuss the department’s strengths, needs, and priorities. You should examine the university’s priorities and consider the work of your department. To protect the resources you have in times of budget cuts or reallocations or to seek increased resources for the department, you must match what you are accomplishing with the mission and priorities of the university. With the forums available to you, you should also take an active role in helping the institution determine its priorities. In particular, you should never tire of reminding your administration that the existence of your doctoral program and your research efforts are defining characteristics of the university.

As documented in the tables at the end of this chapter, at all but a small number of the very best doctoral programs in private universities there is a strong correlation between the size of the undergraduate instructional program and the size of the graduate program. Thus, the opportunity to build a quality research and graduate program depends in part on the size of the undergraduate program. It is not too great a stretch of the imagination to believe that inadequate attention to undergraduate education will place research and graduate education at risk. This is, of course, consistent with the arguments of Kirwan and others that we must place greater emphasis on undergraduate education if we are to protect America’s commitment to the research university.

More than anyone else, it is your responsibility to convince your administration that an excellent undergraduate mathematics program is worth paying for. Indeed, you must remind them that quality undergraduate mathematics instruction, with or without innovations, is a labor-intensive activity.

One of the strongest arguments available to mathematics departments is a combination of the centrality of the discipline together with the size of the instructional program. Many departments can point to the fact that they provide as much as 7 percent of all instruction at the university. Virtually every undergraduate takes at least one course from the department, and in many undergraduate colleges, in any given semester, between 25 percent and 45 percent of all students are taking a mathematics class. If retention of undergraduate students is important and if the university is trying to make a greater commitment to undergraduate students, then the mathematics department is central to their success or failure.

At the same time, this argument can backfire inasmuch as 88 percent of all instruction offered by the department is at the freshman and sophomore level. Deans who are looking to trim costs often ask whether this is instruction that can be offered by lecturers and other part-time instructors. An analysis of many departments reveals that only about 4 percent of the students taking mathematics courses are at the graduate level and another 4 percent are students who are majors in the department. Evidence of faculty interest and involvement in calculus instruction and in the offering of high-quality courses, both as part of the university's general education efforts and to meet the mathematics instruction needs of future teachers, engineers, and scientists, is important to preserving the link between the size of the instructional program and the size of the research faculty.

The essay, "A View from Above", written by Professor Jim Infante, dean of arts and sciences at Vanderbilt University, and included in this report, provides valuable insights into how your proposals to your dean will be judged. In planning for your meeting with your dean, it might be appropriate to take stock of your department's strengths and weaknesses with respect to the following aspects of the department's work:

- Research
- Interdisciplinary work
- External funding
- Graduate education
- Remedial and other precalculus instruction
- Calculus
- General education
- Teacher preparation
- Majors
- Outreach
- Diversity

Research. As noted in the previous chapter, this report consciously says little about research issues. However, in the context of talking to the dean, the following comments on research seem appropriate. Mathematics department chairs often find it difficult to defend their research program, in part because of comparisons to other science disciplines. Physicists, biologists, engineers, etc., tend to publish many more papers than mathematicians and attract much larger external funding. They can fund more graduate students and postdocs than almost all mathematics departments. Mathematics departments also suffer from inadequate media coverage of their research and an absence of ways to document the quality of their faculty based on various forms of public recognition. For example, mathematics lacks anything comparable to the “fellows” designation of the American Statistical Association. Nonetheless, mathematical research is widely respected for its deep intellectual nature. Most educated people are aware that the world we know today could not exist without the tools and knowledge that grew out of mathematical research of the past. While other disciplines sometimes chide mathematicians for being too far removed from real-world problems, they still expect that some of this far-removed thinking will prove invaluable in the future.

There are a number of National Research Council reports and articles in the AMS *Notices* that document important practical uses of contemporary mathematics, such as the importance of group and number theory in cryptanalysis, differential geometry in unified field theory, wavelets in image compression, scattering theory in magnetic resonance imaging. Thus, the importance of curiosity-driven research lies both in the elegant and powerful mathematical theories it creates and in “the unreasonable effectiveness” (to use Eugene Wigner’s phrase) of this mathematics in science and engineering. The leadership in a mathematics department needs to educate the university administration and colleagues in other departments about the mathematical research enterprise—its vast spectrum, its interconnections, and its impact.

Interdisciplinary Work. Research and education today are assuming an interdisciplinary character. Unfortunately, as mentioned in the focus group discussions with deans (Chapter 6), all too often deans see their mathematics departments as “insular”. However, most mathematics departments today have a substantial amount of interdisciplinary collaboration going on in research and/or in teaching. Sometimes it involves, say, some physicists at another institution who work with some mathematicians who in turn collaborate with faculty in your department. It is important for a department chair to be fully informed about all these activities. Also, as noted in the previous paragraph, more and more of the problems mathematicians work on today have important connections to other disciplines. There is much to be gained by trying to build additional bridges to faculty in other departments on campus (this can be done both through research partnerships and through education initiatives) and putting to rest the charge that mathematics departments tend to be insular.

External Funding. Many university departments, especially in the sciences, are judged in large part by their ability to generate external funding. While administrators know that the external funding for mathematics research is far below that in the sciences, total funding and the percent of mathematics faculty with external funding are still important to administrators and to mathematics departments. Moreover, substantial external funding does exist in applied mathematics and mathematics education. Deans are much more likely to commit university funds to research or educational initiatives when there is evidence that their support will help secure funds from some outside source.

Beyond funds for faculty summer salaries, computers, and graduate assistant stipends, external support can play a vital role in the quality of departmental life.

Most universities return to departments a portion of indirect cost funds, which can be an important, though modest, source of discretionary funds. Because of the importance of external funding, it is valuable for departments to create a culture of proposal writing. This includes an attitude, common in other disciplines, of not treating a rejected proposal as a failure, but rather as a challenge to learn from the referee reports, revise, and resubmit the proposal.

It will be increasingly important for departments to actively seek donations from alumni, businesses, and foundations to provide for scholarships, educational initiatives, and research support. Even modest discretionary funds to improve such "quality-of-life" issues as visitor support, social activities for students and faculty, and travel can be a bracing tonic to a department. Close coordination with your university's development office can be crucial to your success.

Graduate Education. While graduate education is a part of their responsibilities that research mathematicians care about deeply, it is seldom a basis for an argument for more resources. In most universities, the number of Ph.D.'s awarded in mathematics is small compared with the number in education, business, psychology, and numerous other disciplines. Thus, an argument based on the size of the program pales by comparison to many others. If, however, the department can offer evidence that the department's graduate program is of particularly high-quality for the university, then the graduate program becomes a department strength the university is pleased to support.

Departments who choose to develop interdisciplinary programs or professional master's programs to meet specific needs (financial mathematics, industrial mathematics) are broadening their mission and advancing their university's ability to provide graduate training in emerging professional specialties. In turn, such programs can help strengthen their university's commitment to the graduate program in mathematics.

Administrators, especially at public institutions, are impressed if departments can publicize the diverse, good jobs their M.S. and Ph.D. students obtain. Departments should provide their graduating Ph.D.'s with training in the nuts and bolts of job hunting, including the preparation of applications, how to target different types of institutions, and trial interviews. Chairs should keep records as to where their graduates take jobs and should assess whether their jobs match the education they received. In addition to knowing which colleges and universities hired their recent Ph.D.'s, it is important to recognize that increasingly students at the graduate level are taking jobs outside academia. For example, a large number of quantitatively based careers in emerging new fields such as quantitative finance require a traditional education in a discipline such as mathematics. If your department is successfully placing students in business and industry, such information may be welcomed by administrators seeking to defend arts and sciences budgets before state legislators.

In considering ways to improve the graduate education offered by your department, it is important that faculty do not change the best part of the graduate experience, the Ph.D. thesis. Project NExT fellows were very positive about their training to do mathematics research. Industrial employers also praise the value of an in-depth experience of working on hard problems. They praise the "analytic thinking skills" that graduates develop, and advise against making significant changes in this core doctoral experience.

Remedial and Other Precalculus Instruction. As many chairs told the Task Force, remedial instruction and, more generally, precalculus instruction pose a significant problem for many departments. In places where there is a large demand for remedial instruction, it can drain resources from the department and time from the department administration.

If remedial instruction results in numerous complaints to the dean or provost, it is surely a matter that must be dealt with before any department priority receives a warm reception from the dean. On the other hand, it is unlikely that the department's needs in this area will result in significant new resources because of the perception that remedial instruction is not very important to the university and that such courses can be taught cheaply. If, however, the department can link precalculus instruction (including remedial courses) to the university's retention efforts, then success in this area can open doors to discussing other priorities.

Calculus. Calculus instruction, on the other hand, is central to many disciplines on campus and is often viewed as the key to whether students will be successful as engineers, scientists, etc. If your administration is convinced that your department cares deeply about calculus instruction and is striving to provide high-quality calculus instruction, they will almost certainly work to find the resources you need for this purpose. In particular, a number of departments have found their university administration supportive of curriculum projects designed to improve calculus instruction at their university.

General Education. In recent years many universities have launched a "general education initiative" seeking some common core of knowledge for all students at their university. Many mathematics departments responded by putting energy into the development of new "liberal education" or "general education" courses for majors in the arts, humanities, and social sciences. Basically, this amounts to developing meaningful (but accessible) mathematics courses for students who will not take some form of calculus from the department. Whenever this fits a university priority, it becomes a basis for arguing for more resources if the department is responding creatively to the university's initiative.

Teacher Preparation. Teacher preparation is an area of collegiate instruction that traditionally has been a low priority in research universities. The recent attention paid to the success (or lack of success) of K–12 students in international comparisons such as the Third International Mathematics and Science Study (TIMSS) has led to a significant increase in attention to teacher preparation and to the continuing education of current teachers. NSF has attempted to focus greater attention on teacher education with its "Shaping the Future" report. The P–16 Initiative mentioned earlier is causing teacher education to be a priority for university presidents who would be hard pressed to show how it was a priority five to ten years ago. Mathematics, of course, is right in the middle of any national priority in K–12 education and the preparation of teachers. Departments that become seriously involved in this aspect of their mission are likely to see benefits for all aspects of department life, and departments that ignore teacher education may suffer.

Mathematics Majors. The education of mathematics majors is, next to graduate education, the part of our instructional mission that appeals most to mathematicians. But our achievements in this aspect of our work are not likely to be perceived as particularly important to university administrators. On most campuses, the number of mathematics majors is tiny by comparison with those in biology, psychology, engineering, business, or education. In a review of doctoral mathematics departments, only five are regularly graduating over 100 majors a year and only sixteen are graduating over 60 majors a year.

Despite the relatively low numbers of students majoring in mathematics, a department's success with majors might be the basis for increased resources if the department can argue that its majors tend to have higher academic credentials than the typical student on campus or that graduates are successful in obtaining outstanding jobs. This argument will be particularly effective on a campus that places a high priority on recruiting outstanding students.

Outreach. Both private and public universities recognize a need to be good corporate citizens in their state or community. Some universities, especially land grant universities, identify outreach (or service) as a significant part of their mission. Mathematics departments have an excellent opportunity to contribute to this part of the university's mission by becoming involved in professional development programs for teachers or by developing special programs for students in the K–12 school system. Such programs can bring very positive attention to your department and college and can often be the basis for proposals for external funding. Responding to the nationwide interest in distance education may be another way for a department to become involved in an outreach activity.

Diversity. Most universities have identified campus goals that may be broadly identified as promoting diversity in our society. These goals can focus on either the success of students or on faculty hiring. Mathematics departments can make a big contribution to their university by developing programs that improve the success of underrepresented minorities in college or that increase the number of women and minorities who are successful in mathematics-based disciplines or in graduate school. Some excellent examples are discussed in Part III of this book.

We Are Not All Alike

As indicated in the first chapter, the Task Force focused its work and its recommendations on doctoral mathematics departments, the ones commonly referred to as Group I, II, and III departments. As noted earlier, they share a common mission, common problems, and common approaches to much of their work. Even the so-called Group V, applied mathematics departments, are very different from the Group I, II, and III departments. For example, these applied mathematics departments have an instructional mix very different from the profile of doctoral departments presented below.

The following table gives the instructional profile for private and public doctoral mathematics departments based on the total student enrollment at each level. Thus, a graduate student who takes three mathematics classes would be counted three times. The Group I departments have been split roughly in half:

GrIA contains the highest-rated departments, and GrIB consists of the remaining Group I departments. While there are 177 Group I, II and III departments, this table uses data from only the 112 departments that submitted data to the AMS-IMS-MAA Annual Report for both fall 1992 and fall 1997. The data below is for fall 1997.

Percent of Total Student Enrollment at Various Levels

	PRIVATE				PUBLIC			
	GrIA	GrIB	GrII	GrIII	GrIA	GrIB	GrII	GrIII
Remedial	0.0	0.7	1.5	1.1	8.9	8.1	7.3	16.9
Precalculus	2.4	5.7	4.0	14.3	11.4	21.7	23.6	19.6
1st Year Calculus	47.2	46.0	45.3	38.8	39.9	34.5	30.6	23.5
Stat or Comp Sci	3.4	9.1	15.9	9.2	2.9	2.9	4.0	8.3
Courses for Majors	16.4	18.7	21.3	21.2	18.9	18.8	13.7	10.4
Other Und Courses	20.4	15.6	9.0	12.2	13.8	11.0	17.3	17.9
Graduate Courses	10.3	4.2	3.7	3.2	4.2	3.1	3.4	3.4

Among the items that stand out are the following:

- Only at the highest-rated 10–12 private institutions (i.e., Group IA) is graduate student enrollment a significant percent of total enrollment.
- Private institutions offer virtually no remedial mathematics and very little precalculus instruction.
- Even the highest-rated public universities have a significant remedial mathematics instruction problem, although it is much greater at Group III institutions.
- First-year calculus is a very large part of the workload at private universities. At public universities, calculus is a much larger share of total instruction for GrIA departments than it is at Group III institutions.

Very few doctoral mathematics departments continue to have instructional responsibilities in the area of computer science. Statistics is more likely to be important for mathematics departments at private universities and at smaller Group III public university departments.

Average Number of Course Registrations – Fall 1997

	PRIVATE				PUBLIC			
	GrIA	GrIB	GrII	GrIII	GrIA	GrIB	GrII	GrIII
Undergrad	1,717	1,841	1,738	1,646	7,789	5,938	4,696	3,437
Graduate	197	81	66	54	338	192	165	121
Total	1,914	1,922	1,804	1,700	8,127	6,130	4,861	3,558

For private universities there is little variation in the sizes of the undergraduate programs for different categories of departments. With the exception of the GrIA departments, the size of the graduate program seems to be driven by the size of the undergraduate program. The GrIA private departments appear to have a significantly larger graduate program that cannot be explained by the size of the university.

For public universities there is a remarkable relationship between the size of the undergraduate program and the departments which had the highest faculty rating in the most recent NRC rankings. Here, too, the size of the graduate program is clearly related to the size of the undergraduate program, with the exception of the GrIA departments.

What conclusions can be drawn from this information? Certainly, to some degree, the size of the faculty and the size of the graduate program are related to the size of the undergraduate program. Only at the highest-rated mathematics departments are graduate enrollments more than 4 percent of total enrollments, and even in those departments the percentages are not large. The message for all of us is clear: A commitment to high-quality undergraduate education is not only the right thing to do but is necessary if we are to protect research and graduate education in our research universities.

Chapter 3
What We Learned

We learned much throughout the course of our work. The extensive comments of chairs and deans in the focus group discussions showed both the nature of the problems we face and the difficulty of achieving simple solutions. Our in-depth site visits (as well as shorter visits to other departments) showed the ways in which some of these problems are being addressed in specific situations. In our meetings we considered all these comments and observations, and we tried to draw conclusions. This chapter describes those conclusions.

1. The nature of academic life is changing.

Most universities find themselves in a period of retrenchment. Reallocation or budget cuts are far more common for universities than the periods of rapid growth that many universities experienced in the '60s, '70s, or '80s. According to the Council for Aid to Education report "Breaking the Social Contract: The Fiscal Crisis in Higher Education", "the present course of higher education—in which costs and demand are rising much faster than funding—is unsustainable." Indeed, this report goes on to say, "What we found was a time bomb ticking under the nation's social and economic foundations: At a time when the level of education needed for productive employment is increasing, the opportunity to go to college will be denied to millions of Americans unless sweeping changes are made to control costs, halt sharp increases in tuition, and increase other sources of revenue."

One need only look at the sweeping changes in health care or at the many states suffering through various kinds of citizen tax revolts to realize that significant change in higher education is possible and that one ignores this possibility at great peril.

Within academia there is growing criticism of research universities for neglecting undergraduate education. The report of the Boyer Commission on Reinventing Undergraduate Education sets out an "Academic Bill of Rights" in an effort to describe the undergraduate education that all students should be guaranteed at a research university. University of California president Richard Atkinson (quoted in Chapter 2) has called for restoring the balance between teaching and research. The NSF report "Shaping the Future" is concerned that "All students have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology."

The mathematics department that does not help its institution to accommodate changes in higher education may find some of its resources reallocated to other sectors of the institution.

2. Departments must invest effort into understanding their university's mission and priorities and then positioning themselves to meet those priorities.

If a university is concerned with retention, attracting honors students, raising academic standards, improving the success rate of minority students, or providing a common core of learning as part of a general education initiative, then surely the department should be asking itself whether it is contributing appropriately to these efforts. If the institution is interested in teacher education or creating a "seamless educational system, from pre-kindergarten to grade 16," then a department should be asking what role it should be playing in this effort.

We do not suggest that a department must blindly follow institutional directives. Faculty can take an active part in helping their university set priorities by balancing constructive criticism with support of institutional goals. For example, rather than merely protesting increased attention to undergraduate or K–12 education, faculty can engage in debate about the most effective means to achieve these goals while maintaining other institutional needs. It is neither appropriate nor effective to block change while offering no constructive alternatives.

When arguing against any ill-considered changes, faculty still need to try to find common ground with their administration and align their department's priorities as much as possible with their institution's priorities. Only by making a meaningful contribution to their institution's priorities is a department likely to receive additional resources.

3. A strong commitment to high-quality undergraduate instruction and to other educational activities should be an integral part of the mission of every doctoral mathematics department.

Undergraduate education is becoming more important in defining the mission of research universities. Thus, many mathematics departments will need to invest more resources (people, time, and money) and intellectual creativity in undergraduate education. Inadequate concern for a department's undergraduate instructional program is sure to bring increased criticism. On the other hand, a department that earns a reputation for excellence in teaching undergraduates generally finds that this pays clear benefits in terms of the resources that are allocated to the department.

The goal of our Task Force is to strengthen research mathematics departments. Indeed, we have spent most of our academic lives in research departments. In the course of serving on the Task Force, we learned of many outstanding examples where departments are successfully responding to the challenge of enhancing their undergraduate program while remaining committed to the development of excellence in research and graduate education.

At the same time, we are concerned that many deans believe their departments have marginalized undergraduate instruction, especially the 60 percent of their instruction at the level of calculus and below. It is in our own best interest to reexamine our commitment to this part of academic work and to be sure that it is an integral part of what we value.

4. Strong leadership is essential to department success.

It is surprising that this statement is not a statement of the obvious, but it is not. Ideally, a department will have a strong department chair who is backed by a solid leadership team (e.g., vice chair, graduate chair, undergraduate advisor) and who has the backing of the senior faculty within the department. Most important of all is a strong department chair who is an effective advocate for the department.

Many mathematics departments appear to fear strong leadership rather than value it. This viewpoint is presumably an outgrowth of a belief that the department is the master of its own destiny; that the department's greatest concerns are internal; and that faculty must guard against the possibility that a strong leader, especially a strong department chair, will impose his or her biases on the department.

Our Task Force believes that much greater challenges and opportunities come from outside the department. In a climate of change, it is important for the department to have a strong chair who can articulate the views of the faculty to the dean (or other administrators) and who can work effectively to secure needed resources for the department.

Repeatedly, our Task Force saw a correlation between a strong department chair and a successful department. Whether the university environment was one of competing for new resources, reallocating constant resources, or determining where budget cuts should occur, strong leadership mattered. At the same time, as our Task Force spoke with chairs it learned of far too many occasions where department culture did not assign appropriate value to the job of department chair or worked to limit the effectiveness of a chair.

Department chairs repeatedly told our Task Force that it took a couple of years to fully understand how their university worked and how decisions were made. The tendency of departments to prefer "rotating chairs" often resulted in chairs leaving their positions just as they were finding themselves able to speak effectively for their departments.

In focus group discussions, a number of deans told our Task Force that they perceive an excess of internal strife in mathematics departments: between pure and applied mathematicians, and between traditional and reform approaches to instructional philosophies at the undergraduate and K–12 levels. Effective department leadership—involving more than just the chair—can create and maintain a healthy environment for the discussion of differing viewpoints, an environment of mutual respect that maximizes both sides' common concerns for quality research and education.

5. Successful departments have established credibility with the university administration.

In site visits and discussions with chairs there was a common theme: successful departments had earned the confidence of their university administration. They understood that the centrality of mathematics carried with it a responsibility to meet the needs of the campus. These chairs were able to cite examples of how they had taken the lead in responding to the challenges faced by a mathematics department in a research university. They were meeting their responsibility for the mathematics education of students from all disciplines and of widely varying abilities. They were actively involved in leadership positions around the campus, and faculty research was making notable contributions both within the discipline and across disciplinary boundaries. Successful departments set goals, strategies, and plans for contributing to the overall mission of the university.

Department leadership is important in establishing the credibility of the department. Deans and provosts must understand the department's priorities, and they must trust the department chair to provide accurate information about the department and to communicate their concerns to the department.

Unfortunately, administrators often assume that responding to complaints about mathematics instruction is a necessary aspect of their position. By demonstrating its commitment to and competence in providing high-quality undergraduate teaching, a mathematics department will gain important leverage in seeking support for other department priorities.

6. The need to defend research will increase.

In very strong departments, say the highest-rated twenty-five research departments in the NRC rankings, institutional commitment to research may be secure. Most other departments may increasingly find themselves needing to defend mathematics research. This can be difficult. Seldom are mathematicians prolific publishers in comparison with their science colleagues. The size of research grants pales by comparison with those in lab sciences and engineering. Mathematics research does not have media attention and public understanding on a par with research in biochemistry, physics, agriculture, etc.

As discussed in the previous chapter, there are new calls for accountability and "measures of productivity", and the need to explain and defend mathematics research will increase. As universities look for things that can be cut or reduced, activities that university administrations do not understand become prime candidates for what they will stop doing.

As the David Report demonstrated, the mathematics community, in concert with friends in other disciplines, can make a strong case for the importance of fundamental research in mathematics and its centrality to many advances in science. Mathematicians need to become more conscious of the need to promote the value of mathematics research to faculty outside mathematics, to administrators, and to the general public.

7. Depending upon the mission of the department and the university, a significant educational outreach program may be appropriate.

Increasingly, universities and departments are challenged to make broader commitments to serve the community in which they are located. Mathematics departments and mathematics faculty can make a major contribution by becoming involved in teacher preparation or continuing education for teachers, enrichment programs for K–12 students, or efforts to help minorities succeed in mathematics. Again, the Task Force found examples of departments that are active in outreach, also have a strong commitment to undergraduate instruction, and continue to excel in research and doctoral training.

8. Issues of diversity are increasingly important to universities and to the profession.

American colleges and universities play a key role in maintaining a classless American society by providing opportunities for citizens to advance economically, professionally, and socially, consistent with their ability and commitment to hard work. Thus, American colleges and universities have always had a special responsibility to society.

One of the most challenging issues faced by higher education is the need to provide meaningful educational opportunities for minorities, especially African Americans, Hispanics, and Native Americans. In science, mathematics, engineering, and technology, we are faced with the added responsibility of providing increased opportunities for women. It is no longer acceptable (if it ever was) for a department to adopt a passive approach of willingly teaching those who come to them but making no special effort to create opportunities and offer encouragement to underrepresented groups of students.

Most universities have identified diversity as a major campus priority. This can mean many things, but it almost certainly includes the goal of increasing the number of women and minorities on the faculty and the number of women (in science disciplines) and minorities who successfully graduate from its graduate or undergraduate programs. For some universities it also means the need to do more in terms of closing the gap between majority and minority populations in public schools.

Mathematicians argue that their discipline has a special role to play in universities because of the centrality of the discipline. This is especially true in terms of enhancing the success of students drawn from populations that historically have not been successful in mathematics and science. If departments make major contributions, they should be able to expect tangible rewards in return.

9. Most departments need to rethink the goals of their graduate program.

Graduate education is connected to the Task Force's findings about the changing environment and the increased importance of undergraduate education. According to the 1997 Annual Survey (second report), less than 20 percent of new Ph.D.'s obtained jobs at a Ph.D.-granting institution in the U.S., including jobs in statistics and applied mathematics departments. At Group I institutions, only about 30 percent of their graduates were hired by Ph.D.-granting institutions. A substantial percentage of these new Ph.D.'s were hired in postdoctoral positions or other temporary positions. It is reasonable to assume that even fewer will eventually obtain tenured positions at Ph.D.-granting institutions. Certainly this prompts the question, For what positions are we preparing graduate students?

There is some good news on this front. Project NExT, sponsored by the Mathematical Association of America, has worked with over three hundred new Ph.D.'s to help introduce them to the many aspects of their new professional life, and the Project NExT Fellows appear quite active at meetings and in professional organizations as a result. A number of departments (e.g., the University of Washington) have become involved in the Preparing Future Faculty initiative sponsored by the Pew Charitable Trust. Working across many disciplines, these programs work with graduate students to help them develop expertise in teaching as well as in research and learn about professional life at a wide variety of institutions, including two-year colleges, liberal arts institutions, and comprehensive universities. The MAA publication *You're the Professor, What Next?* offers a wealth of essays about programs designed to help prepare graduate students for the profession.

A number of departments have worked to prepare graduates who are attractive to American business and industry. It is interesting to note that in the Annual Survey of new Ph.D.'s, the number of jobs in business and industry reported was 248 in 1997. This compares quite favorably with a total that averaged about 100 in the 1980s and was only 114 as late as 1994.

The National Science Foundation's new mathematical sciences initiative, Vertically Integrated Grants in Research and Education (VIGRE), ties several of these themes together. At the graduate level its program announcement calls for restructuring of graduate education to integrate training in research and teaching, along with outreach experiences either in industry or in local schools.

Since the mid-1990s the number of first-year graduate students and the total number of mathematics graduate students at Ph.D.-granting institutions has been dropping dramatically. While this may be a "market correction" in the number of new Ph.D.'s attributable to factors beyond departments' control, it is worthwhile nonetheless for a greater number of mathematics departments to reform their graduate programs with an eye toward preparing graduate students for teaching positions in non-Ph.D.-granting institutions and in business and industry.

10. Both teacher preparation and K–12 outreach merit a greater share of the time and attention of mathematics departments.

Most research mathematicians work at institutions that produce significant numbers of teachers at both the elementary and secondary level. All too often, teacher education is in a separate school of education and largely distinct from the work of the mathematics department, and few, if any, of the tenure-track faculty are involved in teacher preparation. Many research mathematicians view courses for elementary school teachers with the same low opinion they have for courses such as precalculus. If K–12 mathematics education in the U.S. deserves criticism (and it surely has received a lot of criticism in the wake of the TIMSS reports), then a share of the blame falls to those university mathematicians who should be playing an important role in the preparation of teachers but are not. It is easy to make the case that among the most important students mathematicians teach are future school teachers—students who will each pass on the mathematics they have learned to hundreds of other young people.

Beyond the preparation of the next generation of teachers, it is likely that colleges and universities will be called upon to play a larger role in the important business of improving mathematics education in the U.S. This will require more mathematicians taking a role in the continuing education of teachers and making a contribution to the public discussion of what is taught and how it is taught. For most departments this is a fertile area for making a contribution to the university's mission.

11. Adapting to changing priorities is a continuing obligation.

Most mathematicians were educated in an environment where the job of faculty at a research university was restricted to research and teaching. Only small amounts of service were necessary to keep the department operating. The current environment requires a continual commitment to justifying the department's activities, arguing for resources, and establishing plans for the future. Today curriculum renewal, K–12 outreach, teacher preparation, and other educational activities all demand significant amounts of department attention.

As much as faculty might like to "fix the problem" and get back to life as it used to be, that is unlikely to happen. At least for the short term, this richer, more complex mission will be the order of the day in mathematics departments.

12. Department reward systems must reinforce department priorities and recognize contributions in all aspects of a department's mission.

It is a simple observation that departments must decide what professional work is important to the department's mission and then find faculty who will accomplish that work. They will succeed only if the department rewards the work it values. A preferred model for a faculty member is the teacher-scholar mentioned in the science strategy developed by the AMS Committee on Science Policy. Our Task Force endorses the CSP's call for respect for and proper rewards to those who help meet a department's total mission through focused effort in teaching, research, or outreach activities. It is inevitable that different faculty will develop differing strengths and different areas where they can make their most valuable contributions.

One mathematics department, in the top dozen in the NRC rankings, provides a striking example of revised priorities matched with a revised reward system. While devoting extensive faculty resources to innovative calculus instruction in small classes, the department's senior faculty voted to grant a named professorship to the leader of the calculus initiative and gave tenure to the head of its mathematics learning center. The department's commitment to undergraduate education and its documented impact on retention rates resulted in substantial new faculty resources for the department to expand the number of innovative calculus classes.

13. Data is becoming much more important.

Department chairs repeatedly told the Task Force that as the demand for accountability or for measures of productivity increase, they need more data. Each department needs information that helps compare the achievements of the department with similar departments across the country. While the AMS-MAA-SIAM annual reports provide much valuable information, department chairs seemed to be indicating that they need even more information to speak for their department or to know when they should be able to accomplish more with current resources.

14. While there are many problems for mathematics departments (and universities), there are also many successes.

Research mathematicians should mix honest criticism with pride in their accomplishments. Mathematics has much to be proud of, both as a profession and in the way it has addressed a number of the issues discussed here. Mathematicians have been as heavily involved in curriculum changes as any discipline in higher education. Scholars from around the world continue to come to the United States for their training in mathematics. American mathematics research continues to lead the world in many areas. Many, many students at all levels trained in doctoral mathematics departments go on to productive careers, not just in mathematics but in other disciplines as well. Mathematicians should keep these accomplishments in mind when considering changes so that they do not abandon those things that make their programs strong.

Much public criticism of mathematics education by mathematicians is aimed at enlightening the mathematics community in order to address outstanding problems. Mathematicians advocating change must take care not to criticize colleagues in public too vigorously or try to pressure them to be penitent. Criticism without balance makes it more difficult to find solutions.

The views discussed in this chapter led our Task Force to the recommendations that are presented in the next chapter. “Balance” is a critical word in all these discussions. Balance between research and teaching. Balance between sometimes conflicting institutional and departmental priorities. Balance between tradition and change; between established practices (many still valuable but some worth rethinking) and new approaches (many well intended but some unrealistic). Striking the proper balance on these issues is the biggest challenge facing the leadership of every mathematics department.

Chapter 4
Our Advice

The two previous chapters describe the environment in which doctoral mathematics departments are likely to exist over the next decade and list observations that our Task Force believes should guide the decision-making process within doctoral departments. This chapter presents our recommendations to the mathematics community, especially to the chairs and faculty in doctoral departments.

First, we offer three guiding principles that are crucial to the success of a mathematics department. They follow from the findings in the previous chapter.

- Understand the mission of the university and the role of the mathematics department in achieving that mission.
- Create an environment that encourages, enhances, and enables the creative work of the faculty and students who together make up the department.
- Obtain the resources, both human and financial, needed to accomplish the goals of the department.

As we stressed in the previous chapter, making the need to understand the mission of the university a guiding principle should not be misconstrued as suggesting that individual faculty or departments should blindly follow wherever university administrators lead. Instead, mathematics faculty, especially the department leadership, should work to become integrally involved in determining university priorities and in arguing for an institutional value system that places high priority on the core values and activities of a research university. However, to have access to these decision-making councils and to have influence in them, a department's leadership will need to have earned the respect of the university administration through its contributions to advancing other aspects of the university's mission.

If your university places great emphasis on the retention of undergraduate students and perceives the mathematics department as the greatest impediment to improved retention, then the department is unlikely to get new resources (for example, for its graduate program) until it convinces the administration that it will contribute to the retention effort. If the department's size and resource base is due in part to the need to provide precalculus instruction to large numbers of students, the department must convince the university that it accomplishes this part of its mission successfully in order to gain administrative support for the department's highest priorities.

Likewise, if the university has assigned a high priority to gaining membership in the AAU (American Association of Universities) or to improving the NRC rankings of its top departments, then strategies for strengthening the research capacity of the department will be supported by the administration.

As we indicated in Chapter 3, most successful departments have established credibility with their university administration and particularly with their dean and provost. They have done this by recognizing clearly their special position (the centrality of mathematics) and the responsibility that goes with it. They have taken the initiative to address the enormous range of challenges they face. The successful department has earned a role as a campus leader by setting and achieving goals that advance the mission of its university.

Before moving to a specific list of recommendations, we offer the following goal for consideration by most doctoral mathematics departments.

> The Department of Mathematics will be a model department whose mission includes a commitment to excellence in both research and educational activities.

There are some important caveats to offer at this point. Each mathematics department must make its own decision as to the proper balance between the department's commitment to research, to graduate education, to undergraduate education, and to other educational activities. There is no one correct model. Instead, we offer some examples where departments have made important contributions to their university through their educational activities and where it appears to our Task Force that all aspects of the department's mission have benefited as a result.

A loud message from the focus groups with deans was the perception that many mathematics departments were not giving adequate attention to their instructional responsibilities. Our goal seeks to redirect this criticism, turning a dean's concern about good mathematics instruction to a department's advantage.

Having advocated instructional excellence, we remind our readers that this book is targeted primarily at faculty who work in doctoral mathematics departments. It is already a part of the basic mission of your university and your department to have a commitment to mathematics research and to graduate education. Almost certainly your institution is, or wants to be, a Research I or Research II institution in the Carnegie Classification. Your continuing concern about this part of your mission is central to defining who you are. It is a concern for the resource base for research that motivates in part the above goal.

Recommendations for Departments of Mathematics

The following recommendations present important components for achieving the goal of becoming a model department at your university. These recommendations are interrelated. A department will have the greatest success if it considers the recommendations as a group and implements as many of them as possible.

1. Develop a plan.

- Assess your department's commitment to research, graduate education, undergraduate education, outreach, and related educational activities.
- Determine whether the balance is appropriate for your university or whether changes are necessary.
- Develop a mission statement and strategic plan that will strengthen the department and enhance its standing with administrators responsible for resource allocation.

This plan must simultaneously be faithful to the values of our discipline and responsive to the needs of your institution. It is wise to consult with your dean early in your planning process. The plan should be developed by the department as a whole and should have the broad support of the faculty. The plan should be summarized in a mission statement that is as explicit as possible. This statement will be a public document that will serve as a reference point in discussions with administrators about the utilization of current and future resources. The mission statement should maximize the strengths of mathematics and minimize any weaknesses. As noted previously, mathematics plays a central role intellectually in the educational mission of a university. It also is central in practical ways: for example, student success rates in mathematics have a significant impact on retention. While research in mathematics may not fare well in terms of external funding when compared to the sciences, administrators still recognize that there is substantial academic cachet in being able to count mathematics among their highly ranked departments.

Many universities require departments to conduct a department self-study on a regular basis (e.g., every five years). Part V of this book offers a guide that can be used for a self-study or an external review. Certainly, if a department is required to make a major investment of time and energy in an external review, it is reasonable to try to make certain that the review serves the needs of the department. Frequently an external review is carefully controlled by an administrator, and the department's greatest concern is avoiding harmful results from the review. Despite the risks, this type of review has the best chance of obtaining needed resources. Such a review is most likely to be of benefit if the department (and the department chair) are able to work cooperatively to plan the review.

Sometimes a department can get more out of a self-study that is completely controlled by the department because such a review permits the department the freedom to be honest with itself about its strengths and weaknesses. The benefit of this type of review is limited to those issues the department can affect through its own actions and resources, as upper-level administrators are likely to ignore any review in which they had no involvement.

This book and the other resources to which it refers can be useful to faculty as they assess their current department and develop a plan for strengthening the department. We hope that many departments will make strengthening their commitment to educational issues a major part of their plan.

2. Make a commitment to quality undergraduate instruction.

No single issue is more important than undergraduate instruction in determining whether research universities, especially public universities, will receive strong support from alumni, legislatures, business leaders, and the general public. We can debate endlessly whether the criticism that higher education has been getting is fair, but the fact remains that universities do not have the public support that they once had and that they certainly need.

Mathematics departments often offer as much as 7 percent of all instruction at a university and a much higher percentage of freshman- and sophomore-level instruction. Ideally, the mathematics department should be a source of pride for the quality of instruction offered by the university. Because most students find mathematics courses to be among the most difficult they must take, it takes special effort for the department to establish a reputation for excellence in instruction, but it can and should be done.

As more states struggle with mounting evidence that many students graduate from high school unprepared for work or college, greater attention is being paid to the need to invest in high-quality teacher preparation programs. Because mathematics is a large part of a K–12 education, we in mathematics departments must be prepared to do more to help prepare high-quality teachers. Some universities prepare hundreds of teachers each year, while others have no program specifically designed to prepare teachers. Clearly, the proper role for the department in this issue depends upon the university's commitment to teacher education.

3. Support outreach. Determine the department's potential role in helping its state and local community, and develop an appropriate outreach mission for the department.

Increasingly, universities realize that they cannot expect continuing support from state or local communities without making a contribution to their well-being. For a mathematics department the most obvious roles are associated with the continuing education of teachers of mathematics and outreach programs for students still in the K–12 educational system. Because of the current attention focused on K–12 mathematics education, a department that has a significant outreach program working to improve K–12 mathematics education is sure to be a source of pride for the university.

If the mathematics department has an applied mathematics group, then research collaborations with regional industry should also be possible. As one other possibility, several mathematics departments have started actuarial tracks to serve the insurance industry. Another idea is to support the university's interest in distance education by offering mathematics courses via the World Wide Web.

4. Broaden the preparation of graduate students. Prepare graduate students for their profession and for the jobs they will obtain, not just for doing research.

Far too many new Ph.D.'s are well prepared to continue a research program but are not prepared to make important contributions to other aspects of the typical college professor's job. The number of jobs, especially tenure-track jobs, that exist in doctoral mathematics departments (let alone Group I institutions) is far less than the number of new Ph.D.'s who are primarily educated for those jobs. Department chairs from bachelor's and master's departments and the Project NExT fellows in the focus groups often criticized the preparation of new Ph.D.'s to be teachers or their readiness for jobs at liberal arts institutions or other institutions where research is a relatively small part of their professional duties. Whether through an organized program such as Preparing Future Faculty, mentioned in Chapter 3, or by individual department action, it is important to rethink graduate education and to be certain that students are broadly educated so that they are prepared for the jobs they will likely hold. Broadening the education of graduate students could include topics as general as developing communication skills and learning to teach diverse groups of students, or topics as specific as offering advice on job hunting, including the preparation of an application or conducting trial interviews.

Over the past decade as new Ph.D.'s have struggled with a very tight job market, increased attention has been given to the apparent gap between the jobs for which new Ph.D.'s are prepared and the jobs that exist. As noted in the previous chapter, increasing numbers of mathematics Ph.D.'s are finding non-academic employment. The NSF VIGRE initiative is encouraging departments to prepare doctoral students for careers in business and industry.

Departments also may want to consider developing a professionally oriented master's program. Master's programs in financial mathematics and in industrial mathematics have attracted substantial attention. The AMS and MER (the Mathematicians and Education Reform Network) held a workshop titled Exploring Options in Graduate Education which pursued this issue. The AMS and SIAM (the Society for Applied and Industrial Mathematics) also sponsor a joint project on non-academic employment, which should provide valuable information to departments interested in an industrial master's program. In addition, the SIAM "Report on Mathematics in Industry" is a valuable resource for departments interested in educating doctoral students for nonacademic employment.

5. Support diversity.

We cannot argue the centrality of mathematics on campus without recognizing that historically mathematics has played a gatekeeper role, disproportionately restricting access of women and minorities to careers in mathematics, science, and engineering. This is a situation we must change.

Mathematics departments have much to gain if they assume a leadership role in creating opportunities for women and minorities at every level, from outreach programs that seek to strengthen our public school system to hiring practices in our departments. Part III of this book has a number of examples where mathematics departments have taken a lead in creating an environment that enables women and underrepresented minorities to be more successful in learning mathematics.

6. Build strong relationships on campus. Faculty should make building strong relations with other departments and the campus administration a conscious department goal.

Building strong relationships with other faculty and departments on campus is an important component of the overall goal of being a model campus department. Many deans told our Task Force in focus group discussions that their mathematics departments were too insular in their view and in the view of other campus departments. The dangers of poor relations with other departments are obvious. From time to time other departments may be tempted to teach mathematics to their own students or to send their students elsewhere for this instruction. New engineering accreditation guidelines may tempt some engineering faculty to propose teaching their own calculus to engineering students. Among the many reasons why departments cannot afford poor relations with administrators is that they are under budgetary pressure to find cheaper ways to meet large-enrollment freshman courses, and mathematics could easily become their target.

The department leadership (chair, vice-chair, and other senior faculty) should consciously cultivate campus contacts, especially with faculty from key departments who send large numbers of students to mathematics classes. These contacts may be developed through conversations at meetings of department chairs, through joint research projects, or through working together on campus initiatives. Other contacts are established when mathematics faculty are seen as good campus citizens, visibly involved in university service. Even social events can contribute to developing friends and colleagues across the campus. Along with these informal contacts, it is still important that department leaders (e.g., the chair or the undergraduate program director) regularly make formal visits to their counterparts in key departments to seek feedback on their teaching and explore possible areas of cooperation—in new campus instructional initiatives, in joint outreach, etc.

Developing good working relations with the campus administration as well as mutual respect lays a foundation for the department to influence decisions that may sustain or enhance its research and teaching program. The chair must lead this effort by communicating how the department advances the university's mission and how the department effectively uses current resources as well as explaining how the department would use additional resources. When differences arise, deans will usually listen to a chair they respect and trust.

7. Invest in strong leadership.

Discussions with department chairs and with deans and our site visits convinced our Task Force that strong department leadership is a key to building and maintaining an outstanding department. While other models may work for certain departments, strong department leadership (particularly a strong chair) can lead the department through a process of rethinking its mission and provides an accountability that assures the university administration that resources invested in the department will be used effectively. While our Task Force learned of some situations where a department suffered from the inability to get rid of an ineffective department chair, a far more common experience was that of a capable faculty member who spent the first two years as chair learning how decisions are made in the university and how to influence those decisions, only to leave the chair position after the third year.

As we have mentioned before, many departments appear focused on intradepartmental concerns and a desire to prevent one part of a department from gaining an advantage over another part of the department. All too often, a department suffers far more from the inability of the department leadership to make the case to the university administration for the resources the department needs to accomplish its mission.

Departments are well advised to seek a capable faculty member and give that person the necessary authority to be a strong chair, and then to support and value highly that faculty member's work as chair. This support should continue as long as the chair continues to be an effective leader on behalf of the department.

The leadership of the department's senior faculty is very important in establishing the goals and priorities of the department. Our Task Force learned of a number of situations where a department's ability to broaden its mission and make a significant commitment to high-quality undergraduate instruction was the result of distinguished research scholars who lent their moral support for the department's commitment to educational issues while having limited involvement in these activities.

Beyond the position of chair, most doctoral departments are large enough to need a strong, capable leadership team. The most obvious positions include a vice-chair for the undergraduate program, the graduate chair and the chief undergraduate advisor. Having senior, highly effective people in these positions is of critical importance to a department. Beyond administering and overseeing essential functions, they share with the chair the responsibility for representing the department in various forums to client departments and the administration. Depending upon the size of the department and the organizational plan, other positions may also be quite important. Such positions are also excellent training grounds for the next department chair. It is important for the department to have a capable team that works together effectively for the good of the department.

Our Task Force also noted a strong correlation between particularly successful educational initiatives (e.g., an actuarial science program, an emerging scholars program for minorities, outreach programs that work with the public schools) and the presence of a single dedicated leader who had created the program. This emphasizes the importance of identifying the right person to lead a department initiative and giving that person the support needed to create a successful program.

8. Individualize faculty workloads.

By far the best model for a faculty member is that of a teacher/scholar who is intellectually curious about teaching and is dedicated to good teaching while maintaining a strong research program. Such faculty make important contributions to the department's research mission, contribute to the graduate program as Ph.D. thesis advisors, and earn praise for the quality of their teaching. Over time they make numerous contributions to the educational mission of the department through involvement in curriculum renewal projects, the supervision of undergraduate research experiences, and various outreach activities. Over the course of a long career, the activities that attract their interest may change, but they can be expected to make regular, important contributions to different parts of the department's mission.

At the same time, it is clear that many faculty find they are much better at one aspect of the department's work than another. Over the course of a long career, faculty who were once quality contributors to the department's research mission may find that research no longer holds the same interest for them or that the quality or quantity of their research has diminished. Some faculty enjoy working with and advising students, while other faculty only grudgingly perform these tasks.

A good department chair will find a way to maximize the contributions of each faculty member. By finding work that is important to the department and which stimulates the faculty member to work hard and make valuable contributions, the department chair is accomplishing the goal of creating an environment that "encourages, enhances and enables the creative work of the faculty." This effort is hampered by a department whose approach is to insist on the same general job description for all faculty, and creates distinctions over time by rewarding some faculty with significant salaries while engaging in near punitive behavior toward faculty who are unable to thrive within a narrowly defined model of a teacher/scholar. This leads to disgruntled faculty who make very little contribution to the work of the department.

A far better idea is to match faculty with jobs that each can do well and that the department will value. Finding such matches requires considerable effort by the chair and the rest of the department leadership. This effort will likely involve a number of possible matches that do not work out, but with patience almost every faculty member can be helped to find a satisfying niche. Below, the Task Force offers several recommendations to the AMS for helping chairs with this and other difficult leadership responsibilities.

If all faculty are rewarded fairly based on their contributions, then the total accomplishments of the department are enhanced and each individual faculty member enjoys a higher-quality work experience.

9. Expand the reward system.

One of the central issues that must be addressed by faculty, especially department leaders, in doctoral departments is the question of whether the reward system hinders or enables a department's efforts to broaden their mission and establish a proper balance between the research and doctoral program and undergraduate teaching and related educational activities. The conclusion drawn by our Task Force is that the reward system is often a barrier to obtaining important contributions to all parts of a department's mission.

Our recommendation to doctoral departments is that the reward system should be guided by the following principles:

- The standard for tenure in a research department should include the expectation that those who are granted tenure have research achievements that constitute a high-quality body of scholarly work and the expectation that they have a demonstrated commitment to teaching at an appropriate level of excellence.
- The most talented researchers should enjoy the support of the university, including opportunity, resources, salary, and rank, much as they are supported at present.
- It must be easier for senior mathematicians to assume a leadership role in responding to many of the other obligations facing the department or the profession, and they must be able to do this with dignity, respect, and reward.
- There should be clear standards of excellence for those whose greatest achievements are in teaching or other educational activities, and faculty who meet those standards should share in faculty rewards, both financially and through promotion in rank.

Currently, for many departments, research achievements are the standard for receiving honor, salary, or promotion. This can result in faculty publishing mediocre research or in unproductive and disengaged faculty at a time when the department has important needs going unmet. Faculty will not spend time on activities that go unrewarded.

For a chair to carry out the preceding recommendation for engaging faculty, the reward system must recognize the full array of ways faculty can make important contributions to the department's mission. A department must determine what work is important to the department and must reward that work.

Recommendations for the AMS

Since its founding, the AMS has enjoyed a well-deserved reputation as the primary professional society for research mathematicians in America. As a result, it is uniquely qualified to provide assistance to doctoral mathematics departments as they struggle to respond to a broader mission and increased expectations from their universities and to determine the proper balance between research and education. The AMS should help these departments turn these challenges into opportunities to obtain additional resources to accomplish their expanded missions.

Our Task Force recognizes that this is not a task that can be accomplished by issuing the right report or set of recommendations. It is not something that responds to a one-time fix. Instead, it must become an ongoing activity that offers assistance to departments as they address the changing environment described in this book. We have gained an increased appreciation for the importance of giving department chairs the opportunity to interact with their peers on a regular basis and for the support that one chair can provide to another. Because departmental leadership will change regularly, there will be a continuing need to provide new chairs with the opportunity to learn about the many day-to-day responsibilities (hiring, tenure and promotion, planning, dealing with university administrators, etc.) that impact the quality of their work and the success of their department.

The Task Force recommendations supplement the annual symposium for department chairs that is held in Washington, D.C., under the leadership of the Board on the Mathematical Sciences (BMS). This symposium offers department chairs from all types of mathematical sciences departments the opportunity to increase their awareness of the major issues facing the discipline, as well as the opportunity to interact with the various funding agencies which support research and education in the mathematical sciences. There is no need to duplicate or compete with this opportunity for department chairs. At the same time, it is our judgment that department chairs at research universities need and want additional services to help them perform their job. We offer the following recommendations to the AMS that we believe, over time, can assist department chairs and their departments in responding to the broad array of challenges that impact the success of a mathematics department.

1. Continue the focus group discussions begun by the Task Force on Excellence.

Our Task Force on Excellence in Mathematics Scholarship conducted fourteen focus group discussions, including nine with chairs of doctoral mathematics departments, one with chairs from liberal arts colleges, one with Project NExT fellows, and three with deans from research universities. While the original intent in scheduling the focus groups was to gain information for the benefit of the Task Force, it quickly became clear that the discussions were extremely beneficial to department chairs. In all, the nine focus groups for chairs of doctoral departments attracted participants from 76 different departments; 32 of the departments were represented in two or more focus groups. Participation rates were highest from Group I and II public universities. Quite possibly these are the department chairs who face the widest range of issues in leading their department and who benefit most from the opportunity to discuss common issues with other department chairs.

The Task Force offers this recommendation to the AMS Committee on the Profession, with the suggestion that there should be focus group discussions for department chairs at each AMS Annual Meeting.

2. Conduct a workshop for new department chairs each year at the Annual Meetings of the AMS/MAA.

At the 1998 Annual Meeting in Baltimore, the AMS conducted a 1 ½day workshop for new department chairs focusing on issues such as tenure, planning, and working effectively with your dean. The workshop was led by three successful chairs of doctoral mathematics departments, including two who are members of the Task Force. The workshop was well received by the participants, and a second workshop was conducted at the 1999 Annual Meeting in San Antonio. We recommend that the AMS continue offering this workshop for 15–25 new department chairs each year. While the focus of the workshop would be from the point of view of the chair of a doctoral department, the workshop should be open to any chair who finds it beneficial.

3. Organize a resource group of experienced department chairs to serve as consultants for departments that seek a self-assessment.

Our Task Force envisions opportunities where a department may want to take stock of what it is accomplishing and consider changes in some aspect of its work. Just as we recommended that departments invest in strong leadership, it is important that the AMS connect individual chairs with others who have experience in leading similar departments. This might happen on the occasion of the appointment of a new chair who wants to determine an agenda for the time he or she will serve as chair, or it may be a response to a regular program review mandated by the university. The department could arrange for one or two members of the resource group to visit the campus, meet with various groups within the department, and assist the department as it reviews its priorities and its goals for the next few years.

An AMS committee (e.g., the Committee on the Profession) could maintain a list of experienced department chairs willing to visit other campuses and serve as consultants.

4. The AMS should initiate expanded data services for doctoral departments.

Every five years the Conference Board of the Mathematical Sciences (CBMS) produces a significant data report on conditions in the mathematical sciences, and twice a year the AMS-IMS-MAA Data Committee produces its Annual Survey (first and second report), which is published in the *Notices* of the AMS. Taken together, this provides a rich resource of information about conditions in the mathematical sciences, including a survey of new doctoral recipients, faculty characteristics, enrollment profile, etc. It might be argued that few disciplines have comparable information about their profession.

At the same time, any discussion with department chairs eventually turns to their need for information they believe is not available but would be beneficial in making decisions and in seeking resources needed by their departments. Departments are particularly interested in data about institutions they consider most comparable to their own. For example, our fuller analysis of the Annual Report reveals that less than 4 percent of the mathematics instruction in Group I Public Universities is at the graduate level, while the corresponding percent for the top Group I Private Universities is over 10 percent. At the other end of the instructional spectrum, remedial instruction is virtually nonexistent in Group I Private Universities but constitutes about 9 percent of the instruction in Group I Public Universities.

One suggestion is that the AMS create an ongoing cohort study for departments using a selected sample of departments from each cohort to provide more complete data each year. This may require providing incentives to those departments involved in order to entice them to do the substantial work required for such data collection. A more refined cohort study, however, would be extremely useful for departments in analyzing their own situations and in making comparisons.

Eventually, the AMS might initiate a voluntary data-sharing project for doctoral mathematics departments. Participating departments would be able to access the database and seek data at comparable institutions on a wide range of topics, such as the mix of instruction (tenure-track faculty, postdocs, visitors, lecturers and graduate students), teaching loads, information on external funding, publication information, etc. The Data Committee would need to determine the criteria for participating, how information would be collected, what kind of information could be requested from the database, and what information could be released about specific institutions as opposed to other information that might only be given for groups of departments.

Getting Started

Some faculty who read these recommendations may conclude that their department has already dealt effectively with most of the issues discussed and that their department has already positioned itself with a balance between research and education appropriate to their institution's mission. Other faculty may read this book and conclude that it is important to begin discussions to reassess the department's mission but at the same time are uncertain how to begin.

The points of view suggested in this book will require a fundamental change in culture for some departments. Faculty must come to value their department's educational work as well as their research achievements. One important step is to see the difference between something being the responsibility of each and every member of the department and being the responsibility of the collective department. Aside from the basic expectation that every faculty member be involved in some form of scholarly work and that every faculty member endeavors to be an outstanding teacher, there is no role that becomes everyone's responsibility. Just as no faculty member would consider it everyone's responsibility to conduct research in algebra or topology or applied mathematics, no one should expect every faculty member to become involved in calculus reform or teacher preparation or summer programs for middle school students.

The challenge is for the department leadership to lead a process that determines an appropriate mix of roles for the department and helps faculty decide which activities are appropriate for them. As indicated earlier, faculty who are making the most significant contributions to the department's research or graduate program may not need to have any role in new educational initiatives except for giving honor and respect to those who lead in these areas. It is particularly important for the department leadership to work to avoid a conflict between research and teaching. Toward that end, we offer the following advice:

- Meet an institutional need.
- Promote change gradually.
- Make a renewed commitment to the research program.

Much of the discussion on recommendations in this chapter has centered around understanding the priorities of your university, working to help shape those priorities, and then making sure that the mathematics department is making a significant contribution to the university's highest priorities. It is with that in mind that we once again stress the importance of meeting an institutional need. If you do, then you should have reasonable expectations that the university will provide the resources needed to accomplish the work of the department.

Few people actually welcome change, especially if it involves change that they do not fully understand or that causes concern for their own welfare. A gradual approach to change offers everyone in the department the opportunity to understand the relationship between excellence in mathematics scholarship, the overall health of the department, and the overall health of their institution. It is also important to pay particular attention to the department's research mission, to make certain that it has strong support from the departmental leadership during any period of time when the focus is on instructional issues. Attention to this issue can help avoid a conflict between those in the department most interested in protecting the department's research mission and those focused on expanding the department's commitment to educational work.

The remainder of this book contains additional information that we believe will be useful. First we offer readers an opportunity to listen to the mathematics community as they expressed themselves in our focus groups. We then take an in-depth look at the educational activities of five departments we visited and report on a number of other examples that came to our attention. Finally we offer a number of thoughtful essays from leaders in the profession and provide a number of resources we believe will be of benefit.