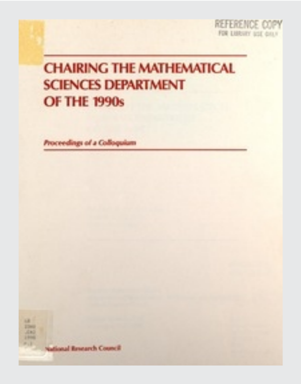

Chairing the Mathematical Sciences Department of the 1990s: Proceedings of a Colloquium, October 27-28, 1989

DETAILS

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AUTHORS

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CHAIRING THE MATHEMATICAL SCIENCES DEPARTMENT OF THE 1990s

Proceedings of a Colloquium
October 27–28, 1989
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Board on Mathematical Sciences
Commission on Physical Sciences, Mathematics, and Applications
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

The fifth Annual Colloquium for Mathematical Sciences Department Chairs, sponsored by the Board on Mathematical Sciences, National Research Council, was held on October 27-28, 1989. The theme of the 1989 colloquium was "Chairing the Mathematical Sciences Department of the 1990s." The focus was on the department chair's role as the manager of a unit of a college or university, having responsibility for administration, research, and teaching. All sessions of the colloquium were plenary and consisted of a panel discussion followed by an open discussion period.

The topics discussed included interaction with administration and other college/university components, how mathematical sciences departments fare in the competition for college/university resources, curricular issues, and funding via federal agencies. Also discussed were extraordinary funding opportunities, nurturing undergraduate programs in statistics, and statistics and operations research in the 1990s.

Each year, the Chairs Colloquium provides a unique opportunity for mathematical sciences department chairs, federal agency representatives, and other interested parties to meet and discuss issues of mutual concern in a pleasant and stimulating setting. This volume contains summaries of the presentations and open discussion sessions at the 1989 colloquium.

Special thanks to Ronald Douglas, Gerald Lieberman, and Jayaram Sethuraman, who planned the program. Thanks are also due to Nathaniel Knox, a consultant for the Board on Mathematical Sciences from Morgan State University, for coordinating and setting up the agenda. Thanks to the staff of the Board on Mathematical Sciences for seeing to the details, especially Ruth O'Brien, Donna Carter, and Jo Neville. Finally, acknowledgments go to Susan Maurizi and Michele Moore for editorial help in preparing the manuscripts for publication, and to Craig Hicks for designing this publication.

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As participants on a panel, deans and provosts discuss the competition among academic departments for the allocation of university resources and how mathematical sciences departments usually fare in this competition. They also make suggestions as to how these departments might compete more successfully and increase interaction with other departments.

MATHEMATICS' SHARE IN THE UNIVERSITY

Ronald G. Douglas
State University of New York, Stony Brook

During the periods 1971 to 1973 and 1981 to 1984, I was chair of the Mathematics Department at the State University of New York at Stony Brook, and for the last four years I have been dean of the Division of Physical Sciences and Mathematics there. One learns a lot in such jobs about making choices and about how universities function. One learns about making choices, because there are almost always more good things to do with money than there is money available. (And indeed there should be if the faculty and chairs are doing their jobs!) Consequently, one learns about how universities function because that is what one needs to know to argue for and get money to do things.

It is a fact that nothing within the mathematics discipline prepares one to be an administrator. Indeed, traits essential to being a good mathematician even work against it. For example, most mathematicians believe that a straightforward, completely logical approach is the best (only?) way to argue and that if their arguments did not carry the day, it was because there was some flaw in their logic or because the other person did not understand them. A related fallacy is that because something "should be done" it will be done. Arguments that rest on such an appeal often do not work, in part because there is little agreement on higher principles. Time spent as a chair usually persuades most mathematicians of the above. Time spent as dean or higher in the administrative hierarchy will certainly do the trick.

Mathematicians have a lot to learn about how universities function and this lack of understanding often costs the discipline. Here, I want to discuss some of the more important facts. Let me add that I am not trying to tell you what to do, only to provide a basis for your making decisions.

First, mathematics departments are viewed primarily in terms of their teaching. That is because mathematics usually teaches about 10 percent of the FTEs at a university, second only to English. Moreover, mathematics is critical in many other programs, and administrators tend to get more complaints concerning mathematics than any other subject. Finally, the size of a mathematics department is almost always directly related to its teaching load.

Our community is very concerned about research. Now, presidents, provosts, and deans are delighted when their mathematics departments (as well as any other department) are outstanding in research and bring their universities recognition and outside funding. However, there is little payoff possible in mathematics because of limited funding, which is thinly spread out. Moreover, because mathematicians tend to be supercritical of one another and use a very narrow definition of research and scholarship, very few departments are recognized as outstanding or excellent. One can contrast this with other fields in which groups in specialties can garner praise. Further in this connection, we tend to write short, nonspecific letters of recommendation, especially when the letters concern awards and prizes, or promotions not involving tenure. We fail to recognize that such honors can benefit not only the individual but also the department and the discipline. The lack of such distinctions can lead administrators to wonder about the quality of their mathematics departments. Our indifference to awards and honors is usually not understood.

Second, we prize people in mathematics rather than special areas or specialties. The "hot areas" are those done by the "hot people." We argue with deans to hire or reward mathematician X rather than arguing that field Y is important, and therefore we must hire or reward X because he or she works in it. Many may disagree with this statement, but I'm convinced that deans will agree with it. Mathematics pushes people as "artists," not as "scientists." I am not arguing that this is wrong, only that this policy has costs. Arguments, whether on the university campus or in Washington, to benefit particular individuals are usually harder to win than arguments for research programs.

Third, mathematicians usually don't understand that university resources are not fixed and reallocation of existing resources is ongoing whether the total budget is rising or falling. Because we don't see the possibility of additional resources, we don't articulate, or argue for, our needs. The tragedy is that not only do we not get the new resources we need, but also we often lose some of what we have because the need is perceived to be greater elsewhere.

Let me now make a number of statements on issues important to mathematics without going into detail.

- Majors are important, and departments must make it worthwhile for faculty to devote time to recruiting, retaining, and working with them.
- The natural constituency for mathematics includes the secondary mathematics teachers; it is important to cultivate and work with them.
- National reports such as *Everybody Counts*[1] and the David report update[2] can be used profitably on campus and locally.
- Mathematics is not the only discipline in which serendipity is important. Everyone desires to be supported and allowed to work on what they wish, not just mathematicians. Again, this is the "art" versus "science" debate, but I don't believe we want to be supported the way the country supports artists.
- Startup funds are very important to many mathematicians. Thus it is crucial to fight for a local policy that provides such funds for new appointments and perhaps for newly promoted faculty. Matching funds for grants such as those involving computers are important also.
- Staff positions, different from faculty positions, are becoming necessary in mathematics. One example concerns a position with the responsibility for maintaining the computer equipment; another might be for a specialist in a teaching laboratory. Funds for such positions will not be obtained just for the asking, but may require continued effort over several years.

Finally, let me summarize what I believe are the three most important points:

1. Arguments for resources are not always won based on logic or appeal to principles;
2. Reallocation is always going on and you are guaranteed to lose if you don't participate; and
3. Recognition of the fact that while research may be your primary goal, mathematics departments are usually viewed in terms of teaching.

While you don't have to think the same way as deans, provosts, and presidents, I believe that understanding how they think should be useful. Good luck!

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[1] National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Academy Press, Washington, D.C., 1989).

[2] National Research Council, *Renewing U.S. Mathematics: A Plan for the 1990s* (National Academy Press, Washington, D.C., April 1990).

THE VIEW FROM ABOVE

Gerald J. Lieberman
Stanford University

A description of my credentials is in order. Before being promoted to becoming a mere mortal, I served in the Stanford administration in several capacities. I joined the administration from the position of holding a joint appointment in statistics and operations research, and serving as chair of the Department of Operations Research. I was asked to become associate dean in the School of Humanities and Sciences. The School of Humanities and Sciences at Stanford is quite large (approximately 30 departments and programs) and there were then three associate deans. An associate dean served as the cognizant dean for approximately ten departments. My role was to serve as cognizant dean for most of the science departments, including the mathematics and computer science departments. Nominally, the home department of the cognizant dean was handled by a different cognizant dean, but clearly, I had important input into the thinking of that dean. After serving in this capacity for three years, I moved into the central administration where I served as vice provost and dean of graduate studies and research.

First of all, having a faculty member from the mathematical sciences serving in an administrative capacity is a net plus for the departments in this area. In spite of knowing where many skeletons reside, a dean from the mathematical sciences will be sympathetic to genuine departmental needs, and even those not so genuine.

Deans generally categorize departments as being "excellent," "good," and "poor." Excellence is rewarded by taking each request from such a department very seriously and, generally, acceding. There is no greater disaster than seeing an excellent department deteriorate. A "good" department is taken seriously, but a dean is more apt to substitute his/her opinions if there is any doubt about the legitimacy of the request. A "poor" department generally gets very little, simply because there are limited resources, and "excellent" and "good" departments have higher priority. Of course, if a "poor" department is targeted to become an "excellent" or "good" department, resources are committed.

A good dean generally compares the activities—teaching load, research assistants (RAs), teaching assistants (TAs), etc.—of a department with those of its national peers rather than with its peers in the same school. Thus the teaching load of the Department of Mathematics at Stanford is compared to the teaching load of mathematics at Chicago rather than the teaching load of physics at Stanford. This is an important point to underscore to you as chairs because these are the data that you should be compiling for your use in making persuasive arguments with your deans.

What are the key elements of the resources of your department? These include faculty salaries, infrastructure, and TA/RA support. In conversations with deans about faculty salaries, comparable data from other similar institutions are invaluable. These data should be made as specific as possible, coming from published surveys, unpublished surveys, and the result of conversations and other sources. These data must be accurate. Again, comparing mathematics salaries with physics salaries at the same institution is not particularly meaningful. Let me qualify that statement by giving an example of the type of internal salary data we kept. We plotted a regression of log salary versus some measure of years of applicable experience for the entire science component of the school. The department chair could then plot the salaries of individual faculty to see how their department fared. Using these data could lead to a persuasive argument in favor of raising the salary level of the entire department. Needless to say, the ranking of salaries within a department is an important consideration. Therefore, raising a faculty member's salary in response to an outside offer is beneficial to the entire department. It is very important for the chair to be aggressive on the matter of salaries.

Infrastructure support is, of course, consequential to any department. However, support for infrastructure is generally very limited, and deans attempt to spread these resources in a fair manner. If the mathematical sciences departments are to increase their share of the pie, they must show that their new needs are unique and vital to the teaching programs of the departments. A good example is the need for micro- and minicomputers in departments in the mathematical sciences.

The final element of resources that I want to discuss is the TA/RA budget. TAs are used in a variety of ways in the mathematical sciences. Some departments use TAs to teach sections of elementary courses; some departments use TAs to handle problem sessions for large lecture classes; and some departments use TAs as glorified graders. In all cases, TA money is an important element for the support of doctoral students. Indeed, the number of graduate students is often a function of the number of TAs needed by the department, and the relationship is complex. Therefore, it is difficult for departments to make invidious comparisons with other departments within the same university or between similar universities. It is true, however, that providing additional TA money is an inexpensive way to "improve" the quality of undergraduate teaching. The quality of teaching is important to every dean, and arguments that conclude that undergraduate teaching will be improved are listened to carefully. Of course, letting TAs teach more sections does not lead to improved teaching. In my experience, research universities do not fund RAs out of general funds; RAs are supported out of government contracts and grants. Thus, a major source of graduate student support must come from resources obtained by individual faculty members. Indeed, that is why the efforts of the Board on Mathematical Sciences in producing David II are so important to the profession.

Finally, what can be done to hire new faculty? A major issue confronting every university is affirmative action. We *must* hire more women and minorities for our faculties, and deans will be very responsive to providing the necessary funding. Furthermore, we will not achieve this goal overnight. Thus, it is vital to increase the pipeline. Funds for minority and women doctoral students will be readily available. Funds for what I call "target of opportunity" appointments are frequently available. Deans are reluctant to pass up the opportunity to add a distinguished faculty member to their roster, even though there are no available positions assigned to the department. It is incumbent on the department, of course, to make the case that the prospective appointment is truly outstanding.

BUILD THE DEPARTMENT'S IMAGE

Frank C. Hoppensteadt
Michigan State University

Mathematics can be an isolating profession. This is reflected in the fact that mathematics departments are often fragmented according to specialization. Another indication of this isolation is that many mathematics faculties have minimal interaction with their colleagues from other departments within the college and the university. This is usually limited to a few committee assignments reluctantly undertaken. Often there is not sufficient contact with local, state, and national groups who have an interest in the department. These groups include former students, school systems, parents of students, and organizations that hire the graduates of the department.

Many departments have established excellent working relations with federal funding agencies by winning grants and participating in peer review. External funding is an important component of a successful department. However, successful departments usually do much more. The following are examples of proven techniques for improving a department's image.

1. Improve the image of the department within the university. Encourage faculty to reach outside the department by taking leadership roles in college and university committees. Develop a task force to work with local and state elementary and secondary education. Develop a task force to attract minorities and women to mathematics and to create a receptive environment for them when they arrive. Create and support a college-wide mentoring program to help with advising and retention of students in mathematics and science. Get to know development officers at the university and get the mathematics department on their agenda.

2. Improve the image of the department with user groups. Track students after graduation and maintain contact with them. A record of fair and reasonable treatment of non-major students and their parents is important. Keep in touch with frequent users of the department: business, engineering, education, science departments, etc. Encourage participation by undergraduate and graduate majors in the department's social and business agendas. Emphasize that the department cares what happens to them while they are in school and after they leave.

3. Make contact with prominent friends of the department. Create a board of external advisors that comprises prominent people in business, government, and politics, getting names of candidates for this board from the university's development office. These people know how students are being used, where their training is deficient, and what are the particular strengths of a department's program; they can provide important access to the central administration on behalf of the department; they can be substantial contributors to a department's development fund; and they can help in placing students in suitable jobs.

Chemistry and physics departments usually have extensive connections in industry. In my experience, they have been very effective in presenting space and budget needs in clear and well-documented ways. They have strong federal support and their students are often prominent in management. Strong industrial support for biology, beyond agriculture, is now emerging for the design of drugs, genetic engineering, and other aspects of biotechnology. Mathematics departments that have pursued computation and applied probability have developed useful industrial ties. Other specializations should develop similar connections. We were surprised at the prominent positions some of our alumni now hold. They are very willing to help us.

A PROVOST'S PERSPECTIVE

Phillip A. Griffiths
Duke University

Before we open the floor for questions, I wish to offer a few observations from the view of a provost. Provosts are generally involved with schools and therefore are less directly involved with departments. However, I will briefly give five characteristics or qualities generally attributed to mathematical science departments by my counterparts at other universities. These views are not arrived at scientifically, and the less flattering characteristics may well not apply to my own mathematics department, whose chairman is in the audience.

First, university administrators are initially well disposed toward mathematics departments. Most of them believe a university cannot be first-rate without an excellent English department in the humanities, an excellent economics department for the social sciences, and in the hard sciences, an excellent combination of mathematics and physics.

A second attribute of departments that is important to university administrators is their own quality control. Here the mathematics department gets good marks. The discipline of mathematics has generally accepted and agreed upon standards. The processes of peer review and of selection of colleagues are based more on quality and not on other issues—e.g., ideology or politics—than in other fields.

Third, on the integration of teaching and research, the mathematical sciences don't fare as well. There is more of a conjunction between the teaching and research functions in, for example, the humanities, where research can in fact be blended with undergraduate teaching.

The fourth attribute is interaction with other departments. Historically, mathematics departments were viewed as being rather isolated. Their chief interactions were with other mathematics departments. This is now changing. Since many problems from other sciences are of interest to mathematicians, we are now seeing much more interaction of mathematics departments with other departments in the university.

Finally, the fifth attribute is what I will call political savvy. Mathematics departments have been viewed as being less interested in campus politics. This is not necessarily good or bad. However, it seems to be changing.

In closing, I would like to emphasize Dr. Douglas' initial point that the way a university functions is not a rational process. This is difficult for us in mathematics to handle. On the other hand, that is the way things are.

QUESTION-AND-ANSWER SESSION

PARTICIPANT: Could you discuss the issue of joint appointments?

DR. DOUGLAS: Some of our discussion today is related to the culture and sociology of mathematics. A person with a joint appointment must live in two cultures, especially if the second field is very different from mathematics. One must address that. Also to be considered is the usual problem of blending two disciplines. One must pick a lead department with the ultimate responsibility for issues of tenure, promotion, and other professional concerns. A joint appointment should be entered with complete understanding of its terms. One should not make or accept a joint appointment and expect to work things out later. That is inviting trouble.

DR. LIEBERMAN: My experience is that the pure mathematics department has not wanted to have joint appointments. There are probably concerns about whether the joint appointment would result in a reduction of one's contribution to either department. However, I think joint appointments are ideal. But one has to make both departments happy. Joint appointments in other fields of mathematical science—statistics, computer science, and operations research—have been more prevalent, easy to make, and very successful.

From the individual faculty member's point of view, there are a lot of difficulties involved in a joint appointment. One has two masters. Additionally, one must produce students in both departments and produce research funding in both departments. In this case, the sum of one's activities generally adds up to more than 100 percent. I would be reluctant to encourage young people to take joint appointments. As they move up and have acquired tenure, the problems become more manageable.

PARTICIPANT: May I speak to that? I try to obtain two appointments, one for each of the two departments involved. Then I allow shared teaching and give both persons the right to direct theses in both departments. This removes the problem of two cultures and seems to work very well.

PARTICIPANT: Several national reports and speakers here today have mentioned the need to get women and minorities into mathematics and mathematics departments. Are there any solutions to this problem?

DR. HOPPENSTEADT: My daughter, who is good in mathematics and physics, is in high school. I want her to go into physics. She went to see her counselor at school. Afterward we discussed her visit. Her counselor had recommended that she go into fashion merchandising.

There is a very strong imprint still directing women away from science. However, some progress is being made. The mathematics department at Michigan State has recruited a number of outstanding women mathematicians who find a receptive environment there. The issue of cultivating receptive environments is difficult. It will take time to change. Many of the departments are dominated by majority males. When "receptive environment" is mentioned to a group of this type, there is no resonance at all. No one understands the meaning of the words. It really takes training sessions to work on the departments and begin raising the issues that face minorities and women coming into the programs.

I have been involved with training, on the Ph.D. degree level, of a number of women and minority students. They have been successful in their careers. However, they have been exposed to a tremendous number of phone calls requesting that they accept appointments with departments because those departments need a woman or minority faculty member. It is staggering to realize that people actually say such things on the telephone. As chair of a department, one must not do that.

The issue of getting the minorities pipeline filled is one of the things on which we have been working. We run extensive programs for students who have finished their junior year. When students are brought in after their junior year in high school, they have a year to make up deficiencies they may have. Thus, they have a chance of entering on the same footing. Also, we have an enrichment program for high-achieving minority students that sees them through mathematics programs. That has been going on for 25 years at Michigan State. These kinds of programs are available at other universities as well. The programs are hard-nosed and students must be well motivated and must work hard to remain in the program. On following the students through, the success rate is dramatic. So special guidance and advising of undergraduates are helpful.

There has been a tremendous amount of discussion of these issues over the last 20 years. We are just at the threshold where many of the environments that have been hostile are becoming more receptive.

PARTICIPANT: I wish to comment on that. We have found that allowing interested female faculty members to teach calculus has helped in getting highly qualified women mathematics majors. They see successful role models. That is critical. It also suggests some problems. We have eight to ten percent minority students. However, it is very difficult to find successful minority role models in any of the sciences. I think that may really be the crux of the problem.

DR. HOPPENSTEADT: I think that is changing. I see more minorities and women in mathematics at the Ph.D. level. But I agree with you, it is a critical issue.

2 CURRICULAR ISSUES

Under this topic, discussion centers on how to create an atmosphere that encourages and motivates faculty members to initiate curriculum studies and stimulate change; the roles of discrete mathematics and statistics; and how to keep up, be relevant, and profit from curricular change.

THE BREADTH AND DEPTH OF CURRICULUM

Frank L. Gilfeather
University of New Mexico

Mathematical sciences departments, in all but a few of the top institutions, are driven by their various instructional roles. There are six distinct and often competing instructional missions for most mathematical sciences departments. Each of these yields unique curricular challenges for us. The purpose of this note is to set out a few of these issues for our discussion.

1. *Graduate students.* The 250 Ph.D.-granting departments are the primary instruments in the current effort to maintain U.S. leadership in our discipline and replace the aging research workforce. In addition, the master's level programs are the feeders from which significant talent, especially in underrepresented groups, will come.

> *Are our programs giving an appropriate education for the varied jobs our students will be taking? Are our programs fragmented between pure and applied? Do we provide sufficient postdoctoral experiences? Is a post doctoral necessary? Desirable? What are possible barriers to underrepresented groups in graduate studies in mathematics? How do we reduce these barriers?*

2. *Undergraduate mathematics majors.* Our ability to stimulate students to pursue degrees in the mathematical sciences and then go on to graduate school will ultimately determine our viability as a discipline. This mission is shared by the 1,500 baccalaureate mathematics departments and is supported by the two-year institutions and the related secondary mathematics programs.

> *Are we identifying mathematical talent early and encouraging it? Is our course selection varied and exciting to our majors? Do we have special honors courses and seminars for our majors? Do we provide monetary and other support for mathematics majors? Special recognition? Can we identify barriers to becoming a mathematics major for underrepresented groups? Do we especially encourage students from these groups?*

3. *Teacher preparation.* How successfully we deal with curricular issues and the quality of our effort here may be our most important task. This mission falls mainly to schools outside the top research institutions and emphasizes the interdepen-dence of all mathematics departments. Future generations of students are affected by the efforts of those training our future teachers.

> *Are prospective teachers challenged and provided stimulating and varied courses? Are they given exposure to computing and modern topics? Are they aware of trends and popular literature about mathematics? Do they share in the "mathematical family" in your department? Do you even know who these students are?*

4. *Upper-division service.* This instructional role is unique to mathematics. No other discipline has as large, or as important, a role in preparing students in other disciplines. With the accelerating emphasis on mathematics

in all fields, this role will be an increasing force in our curriculum and will have an impact on our departmental priorities.

Do you regularly consult with the client disciplines to guide curricular decisions in these courses? As appropriate, do you provide computational support for these courses? Are they relevant as taught? Do faculty know why they are teaching these courses and to whom?

5. *Introductory service.* Mathematics is truly the gateway to most fields of study and is becoming more so each year. This fact will surely have an impact on our instructional programs in all post-secondary institutions. These courses, through calculus and including introductory statistics courses, are required in order to begin study in all science and engineering fields and increasingly so in the social sciences.

The fact is that the largest high-school-level instructional units are found in our universities and colleges, not in our high schools. The transition from secondary to post-secondary mathematics instruction will continue to be a major issue facing our mathematics departments in all but the highly selective institutions. These issues become most urgent as we seek to bring more underrepresented groups into science and engineering fields.

How relevant are your pre-calculus courses? Do you know if you prepare students adequately for the transition from pre-calculus to calculus and from calculus to engineering and advanced mathematics courses? Is your "business calculus" simply a hurdle? Are you being used by others as a filter? If so, what do you do? What use of calculators do you make?

6. *General studies.* Mathematics is becoming a required subject of liberal arts. This trend will create pressure to redefine these general courses and add staff to accommodate the additional students. These courses are hard to teach because the students often have poor mathematics skills and have anxiety about quantitative concepts and logical reasoning. While this is the least critical of the instructional areas, it takes on real meaning if, for example, your institution recently introduced a "quantitative reasoning" component.

Are these courses of value? Should a liberal education include some calculus instead? Is this a place for introductory discrete mathematics or a statistics/probability course?

The instructional missions set forth above are clearly interdependent. Yet each is distinct, because each has a unique set of challenges and critical issues. Each mission requires a lot of our attention, energy, and resources (human and financial). Clearly, not all faculty see all these missions as of interest or of importance. This makes the challenge for us as department leaders even more difficult. How well we deal with them will shape our future as mathematics departments and ultimately as a nation.

THE ROLE OF THE CHAIR IN SHAPING THE CURRICULUM

Michael C. Reed
Duke University

This presentation highlights four points related to the chair's role in shaping the curriculum.

1. *Mathematics departments are treated quite poorly by university administrations.* Mathematicians have higher teaching loads than our colleagues in the sciences. Departments have so few faculty resources that much of the teaching burden is borne by graduate students and part-time people. And then, the administrators complain that teaching isn't very good. Many university faculty members and administrators regard mathematics as a service department for the rest of the institution. The good news is that we can all agree on this. The bad news is that this situation is mostly our own fault. Most mathematicians are not good entrepreneurs. They have contempt for "public relations" and they have a very short-term view of university politics. As a result, typical departments do not have strong allies in other departments or in the administration. In addition, most department chairs are very unimaginative in the use of the faculty resources that they do have.

2. *Differential teaching loads are a necessity.* In most departments, nearly everyone has the same teaching load; in the major universities it is two courses per term, two and one. For simplicity I will discuss only this case. Most faculty feel that they have two responsibilities, teaching and research, and that when they have finished in the classroom they have discharged their departmental duties. The rest of their time is their own, although they occasionally agree to sit on departmental committees or perform "other" service. The trouble is that curricular reform (that is what we are here to talk about) and many of the tasks that are listed in item 1, which are very important for the long-term health of the profession, all fall into this "other" category. Faculty members are willing to participate, as long as they don't have anything important to do. The only way to break the logjam created by these attitudes and to free up time for curricular reform and other service is to have differential teaching loads. Salary differentials for a given year are typically small and only partially under control of the chairman, and promotion and tenure decisions will simply not be made on the basis of such "other" activities. That leaves differential teaching loads as the only effective carrot and stick that a chairman can use to encourage and reward faculty effort. Let me clearly state what I think those teaching loads should be. I believe that faculty members with excellent research programs (say at the level normally supported by the NSF or other federal agencies) should normally teach one and one. I believe that faculty who do not currently have significant research programs should teach three and three. Faculty with "high" teaching loads should be allowed to reduce the load by important service to the department and the profession. I for one would interpret "service" very broadly to include, for example, involvement in local and state elementary and secondary education, programs to encourage women and minorities in mathematics, etc.

I am familiar with the usual objections to differential teaching loads (Who will decide? You are creating two classes of faculty! This will interfere with the collegiality of the faculty!), and I think they are very weak. Faculties or chairmen who routinely judge hundreds of job candidates can create mechanisms for making these decisions with reasonable fairness. Faculty at the research institutions who do not have active research programs are already treated as less valuable. And, as for collegiality, I can only say that we are a professional organization, not a country club. Let's face it; teaching two courses a term is not, in and of itself, a full-time job.

It would be humiliating to list mathematicians from the 1920s, 1930s, and 1940s who taught three (or more!) courses per term and whose research contributions exceed those of most of us at this meeting, so I will refrain.

3. *Let's experiment.* I am continually amazed at the resistance of the mathematics community to experimentation with the curriculum and with teaching methods. We really are stuck in the mud. Perhaps it's because mathematics is forever that we think the methods of teaching should be forever too. This does not mean that I am convinced that the new ideas, computers in the classroom, computer labs, writing in mathematics courses, joint student projects, and so on, will turn out to be reforms that we will want to keep, to enshrine as the new standard. But, I believe that all departments should experiment and try new things.

4. *Nothing beats knowing some current exciting applications of mathematics.* Let's face it, we won't win their hearts with the harmonic oscillator. That's a seventeenth century application and they've all seen it before anyway. There has been a tremendous explosion of mathematics outside of the physical sciences in biology, economics, business, and computer science, as well as dramatic successes in the physical sciences. Many of these applications are exciting and serious but use only undergraduate mathematics. Why aren't they in our courses? Mainly because most mathematics departments have few faculty who are knowledgeable. It simply takes a tremendous amount of work for a typical mathematician to find some juicy examples from these new areas, so it's just simpler to use the old stuff from the seventeenth century. Here is a perfect example of how a chairman could use faculty resources creatively. He can take a faculty member who has a closet interest in (say) economics, and give him or her the job of creating 25 excellent examples of the applications of mathematics in economics, five for calculus, five for the linear algebra course, five for the ODE course, five for linear programming, and five for the graduate real variables course. Faculty compensation would be one course off per term. Not only would the courses be better and more exciting, but the faculty member would be enriched and the department would gain valuable connections to the economics department.

INTERDISCIPLINARY STATISTICAL SCIENCES

Ingram Olkin
Stanford University

My talk is the summary of a report of a panel to the Institute of Mathematical Statistics concerning cross-disciplinary research. The following is the introduction of this report[1] and sets the stage for the discussion.

The development of modern statistics has its origins in applications. Driven by the need to solve practical problems in agriculture, industrial production, medicine, and many other fields, statisticians have achieved signal advances in theory and methods. In turn, statistical thinking has greatly stimulated the development of virtually all areas of science. The application of the principles and methods of experimental design, the role of statistical modeling, and the pervasive use of simulation methods are but three instances of statistical developments that have had a deep impact on science. The widespread influence of interactions between statistics and other disciplines and the very nature of statistics as the science of the "meaning and use of data" establish the statistical sciences as the discipline with the most central and complex cross-disciplinary activity.

It is consequently no surprise that there is almost universal acceptance among the statistical profession of the need to nurture cross-disciplinary research. Yet, the last few years have witnessed growing concern about the health of that part of the research enterprise devoted to cooperative efforts between statisticians and other scientists.

Questions raised include:

- What are the current needs for new thrusts of cross-disciplinary research?
- To what extent are statisticians and scientists paying sufficient heed to the opportunities and challenges of recent advances in computing technology and large-scale data collection?
- To what extent is there adequate funding for cross-disciplinary research?
- To what degree do institutional structures support and encourage cross-disciplinary collaboration?
- How can perceived needs for stimulating cross-disciplinary research be addressed without impairing support for the disciplines?

While theoretical developments and the application of statistical methods have proceeded rapidly over the course of this century, it is only recently that the advent of inexpensive and powerful computational resources has opened the way for major advances in the statistical study of complex models. At the same time, greatly expanded data collection and processing capabilities have created opportunities and challenges for analysis with large, multidimensional data sets.

Yet, the statistical and scientific communities appear to have paid insufficient attention to the opportunities presented by these advances in computational and data resources. Moreover, although it is increasingly evident that failure to adopt useful statistical methods and techniques is costly to science and industry, there has been a lack of a concerted effort to address the interactions between statistics and other disciplines.

In recognition of these circumstances and the need to answer the questions raised above, the National Science

[1]Reprinted, with permission, from *Cross-Disciplinary Research in the Statistical Sciences* (Institute of Mathematical Sciences, Hayward, Calif., September 1988).

Foundation (NSF) in 1985 funded a proposal by the Institute of Mathematical Statistics (IMS) to assess the current status of cross-disciplinary research involving statistics and to make recommendations for its future. Four divisions within NSF—Mathematical Sciences, Social and Economic Science, Chemistry, and Cross-Disciplinary Research (Engineering Directorate)—provided funding. The IMS formed a panel to carry out the project whose members were Alfred Blumstein, Amos Eddy, William Eddy, Peter Jurs, William Kruskal, Thomas Kurtz, Gary McDonald, Ingram Olkin (cochair), Ronald Peierls, Jerome Sacks (cochair), Paul Shaman, and William Spurgeon.

We note that the terms *cross-disciplinary, multidisciplinary*, and *interdisciplinary* have at times been used interchangeably. We take advantage of these alternatives in order to draw some distinctions. Following Epton, Payne, and Pearson (*Managing Interdisciplinary Research*, John Wiley & Sons, New York, 1983), we adopt the following definition: a research task requiring a combination of disciplines is *cross-disciplinary*. In contrast, the terms multidisciplinary and interdisciplinary refer to the organizational forms used to carry out cross-disciplinary research. The *multidisciplinary* form is that in which research tasks are carried out by separate single-discipline units and their results brought together by a coordinator. In the *interdisciplinary* form, the research is carried out collaboratively and interactively within a single unit representing all the necessary disciplines. Our report is about cross-disciplinary research that has a statistical component—the work may have multiple objectives, but it includes the advancement of statistical science. One of the concerns of our study is the development and support of organizational structures that will foster successful cross-disciplinary work.

The panel developed a series of recommendations to enhance support for cross-disciplinary research. Part B of the report presents our recommendations, which are addressed to the National Science Foundation and other funding agencies; to research managers and members of the statistical community resident in academia, industry, national research laboratories, and statistical agencies; and to the professional associations.

Part A of the report presents the findings that underlie the panel's recommendations. The panel believes that advances in statistical theory and methods are stimulated by the need to solve problems in substantive areas and that these advances in turn stimulate the development of substantive knowledge. In support of this premise, Section A.1 summarizes, and Appendix I describes more fully, several prototype examples of past success in collaborative research among statisticians and scientists in other fields.

The panel believes that there are important current problems in many disciplines that would greatly benefit from close collaboration among statisticians and other scientists to push forward the frontiers of theory, methods, and knowledge. Indeed, without adequate support for cross-disciplinary research, there is a risk that major opportunities for significant new developments in many fields will be lost. To indicate what is needed, Section A.2 summarizes, and Appendix II describes more fully, several examples of specific research areas that could greatly benefit from cross-disciplinary work. A persistent theme is the impact of large-scale computer technology and data sets, both of which afford great potential to researchers but present equally formidable problems of effective use. Indeed, the phenomenal amount of data being generated in all of the sciences is creating a need for new ideas to deal with the compression, presentation, and analysis of large data sets. The panel believes that statisticians must give priority to developing adequate theory and methodology for handling the complex models and large multidimensional data sets that characterize today's scientific research.

The panel finds constraints in funding and institutional support for cross-disciplinary statistical research on the part of NSF and other funding agencies. This conclusion rests in part on a review presented in Section A.3.1 (with additional details in Appendix III) of reports from other committees and panels over the past 10 years that considered the health of cross-disciplinary research. Uniformly, these reports document problems in obtaining support for work proposing to develop statistical theory and methods directed to the application needs of other disciplines. The panel also notes that recent funding problems experienced by federal agencies generally are having a deleterious impact on statistical research and particularly on collaborative work. Section A.3.2 presents some data on this point. Although the panel calls for many of the same ameliorative efforts that earlier committees urged, we point to some approaches that can have a marked impact on the support and encouragement provided by funding agencies for cross-disciplinary research.

The panel further finds that institutional support for collaborative research between statisticians and other scientists in academia and industry is problematic and could be substantially improved. There are successful efforts by some government agencies such as the Bureau of the Census, the Bureau of Labor Statistics, and the National Center for Education Statistics to bring together multidisciplinary teams for needed research programs. The example set by these agencies and their approaches are worth transferring to other agencies and other arenas. Maintenance of these efforts and added support for them by other interests in and out of government are recommended.

Section A.4 summarizes the responses to a questionnaire sent by the panel to statistics departments and programs in colleges and universities across the nation. The information gathered from this survey provides useful insights into problems connected with cross-disciplinary activity. (Appendix IV gives a full description of the survey.) The panel has sought in its recommendations to take account of the perceptions of the community at large in identifying targets of opportunity and suggesting approaches to buttress and extend the support for cross-disciplinary research in all environments in which statisticians work.

Finally, in order to provide a necessary long-range view and to establish a structure for maintaining the health of the field and its cross-disciplinary character, the panel recommends the establishment of an Institute for Statistical Sciences. The panel calls upon professional societies, committees of the National Research Council, the National Science Foundation, and other units in academia, industry, and government that have responsibility for the well-being of the discipline to review the panel's findings and recommendations and to act upon them.

QUESTION-AND-ANSWER SESSION

PARTICIPANT: I was intrigued by Dr. Reed's ideas concerning the involvement of faculty in curriculum development in institutions other than our own. Our teaching loads are similar to yours, a little heavier for those who do no research. I understood you to say one could go to one and three and allow those with three courses to buy their loads down to two. Do you have any suggestions as to where one might find the resources to do that?

DR. REED: If you do not get the additional resources to teach the required courses, then cancel them. I am not implying that you should take this action without thorough consultation with your department and your dean. However, for historical reasons mathematics departments are understaffed in terms of teaching. Over the last 30 years, we allowed university administrations to decide that essentially all freshman teaching would be done by nonprofessionals, by graduate students or by part-time staff. As a result, most departments do not have the number of faculty they need to support the kind of undergraduate program in which there is sufficient faculty-student contact, seminars, and faculty-supervised projects by undergraduates. Those things are extremely expensive in faculty time. Most universities do not have the faculty time. We are understaffed. Additionally, now we are being asked to take on many important social responsibilities. Something has to give. We cannot do all these things. We must make that clear to the university administration.

PARTICIPANT: Part of the answer to the question seems to be that by aggressively dealing with issues that the department and the university consider important, one is in a good position to get resources allocated to his department. As Dr. Douglas said earlier, we are dealing with issues to which the university gives priority in its strategic plan.

PARTICIPANT: I would like to point out that the freshman experience is where, perhaps, we do not do our best job. Reassigning people who have not been strong in research to this extra teaching load may not be in the best interest of undergraduate students.

DR. REED: Running a department is a human operation. The faculty in your departments are your colleagues. Many of them will have talents and time that would be useful for one or another of this broad range of issues. We must get out of the mode that we only do research and meet classes in the classroom. Chairs must manage departments in a way to which we are not accustomed. We must consider the faculty as multitalented and multidimensional people who have a variety of things to offer. We have not found ways of using all of those talents. One needs to look across the board and, over a long period of time, encourage faculty into these other things.

PARTICIPANT: I am chairman of a department of operations research at an engineering school. My position as chair is only one-third of my time. We have a three-course teaching load. The only way to reduce it is to divide off with research or proposal writing. I will have to approach my dean and request release for my faculty to help with various programs and tasks. I am trying to do all those things as chair. A faculty member can legitimately say, "I am required to teach three courses or buy off some of my time, which means I must run after money and do the work." Given that my school runs in the red, it will be difficult just getting down to a reasonable teaching load.

PARTICIPANT: I am from a master's degree-granting school. One of the things about schools of this type is that faculty are required to be superhuman. They must teach 18 hours per year, do research, go out into the public schools, serve on committees, increase minority representation, and so on. Many of the things Dr. Reed discussed in the response concerning shifting personnel are extremely important. This is one place where the mathematical sciences community fails. For instance, we have people in my department who really are excellent teachers. They work very hard on a variety of service projects with the public schools, for example. However, it is very difficult for them to get pay raises equivalent to those generated by publishing research articles. The whole mathematical sciences community must face the issue of rewarding persons for work other than publishing.

DR. GILFEATHER: If one can identify excellence, then I would say that this person is in the front line of trying to do something about adjusting the reward structure. It should be based on excellence.

PARTICIPANT: Consider a person who is active in research but does not generate continuous support, or a young faculty member who has not yet generated support but is expected to generate support. These are the persons who should be nurtured. Is there room for a middle ground? Could there be three differential teaching loads?

DR. REED: I think junior faculty should automatically get low teaching loads. The burden comes with tenure. If one is a tenured faculty member in an institution of higher education, there are serious responsibilities that go with the job. It is the responsibility of the chair to get faculty members to live up to those responsibilities.

PARTICIPANT: Do you have any comment on the relationship between effective curricula and class size or effective teaching and class size?

DR. GILFEATHER: Curriculum, class size, and so forth, are driven by resources. We have been discussing resources. As we try to address other things, as Dr. Reed has suggested, I do not see lowering classsize as a result. There are variables. If one variable is manipulated, then the others are affected.

3 FUNDING OPPORTUNITIES

Discussion under this topic encompasses how to motivate faculty to apply for grants, both as individuals and through cooperative efforts; some extraordinary sources of grants, including equipment and facilities grants; and how to enhance cross-disciplinary collaboration and research.

LOVE'S LABORS WON: NONCONVENTIONAL FUNDING FOR THE MATHEMATICAL SCIENCES
James Glimm (Organizer), State University of New York, Stony Brook

OUTSIDE FUNDING
Daniel Gorenstein, Rutgers University

DEVELOPMENT GRANTS
Calvin C. Moore, University of California

LOVE'S LABORS WON: NONCONVENTIONAL FUNDING FOR THE MATHEMATICAL SCIENCES

James Glimm
State University of New York, Stony Brook

"Love's Labors Won" was chosen as the title for this presentation to remind you that this is not a discussion of how to apply for a grant. It is really a discussion of how to win a grant. We assume that you are familiar with the process for obtaining support from the National Science Foundation. Here we are considering the complement of the National Science Foundation/Division of Mathematical Sciences.

The winning of a grant begins, of course, with the submission of a proposal. So we will consider the ingredients of a good proposal. First, a good proposal should contain quality science. I will not attempt to advise you on that issue.

Second, the proposed project should have realistic goals and potential applications. The list of goals should include objectives that can be achieved in one to three years. Longer-range goals may also be included.

A third ingredient of a good proposal is political support. For example, there may be a technology transfer component to the proposal. In this case, political support means that one has identified a user group and the proposal contains a mechanism by which the user may interact with the new science as it is created. That support could be expressed in the form of letters from the potential users. Stronger support consists of letters from potential purchasers of the new science who pledge to contribute to the support of the effort.

Finally, the requested level of funding must be realistic. This includes the proposal itself and the costs of actions that might be based on the proposal.

These ingredients for a good proposal were set forth by a member of the New York State legislative staff at a symposium I attended on studies of water quality on Long Island. However, there are some lessons there for mathematicians, also.

So, how does one win a nonconventional grant? Knowledge of the program is a key ingredient. Each program has goals, people, and program officers. It is essential that a grant applicant have this information. Additionally, nonconventional grants usually require cooperation with other disciplines. Often mathematics is only a part of the project.

The reputation of the proposer is also important. This is related to the quality of the science involved. Finally, successful nonconventional proposals usually have some level of cost sharing from various areas, including the university, the state, the community, and the private sector.

I will close with a brief checklist of things to do in preparing for the submission of a nonconventional grant proposal.

1. Make an inventory of your opportunities.

   - What are the local industries? What are the technical problems of local industries? Invite the technical staff to have informal discussions with faculty and students so that you can determine the mathematical aspects of their problems. Try to place a student on the staff.
   - What are the local governmental laboratories? (Use the same approach as above.)

- What are the strong technology and science departments in your university? What kind of mathematics do they use? What courses do they teach? Is there a possibility of joint Ph.D. theses?
- What are the existing contacts from your department?
- What are the areas of mathematical strength in your department? What are the potential applications of these areas? Based on these strengths, can contacts be created?
- What are the important problems? Where does technology fit in? What mathematics is involved?

2. Identify funding programs.

   - University
   - Governmental (state, local, and federal)
   - Industrial
   - Private

3. Begin with small-scale internal resources.

   - Seminar
   - Key visitors/technical conference
   - Cross-disciplinary students

4. Look for promising problems.

   - Establish a research program.
   - Establish interdisciplinary collaboration.

5. Learn the subject from the viewpoint of other disciplines.

6. Pre-review proposals.

OUTSIDE FUNDING

Daniel Gorenstein
Rutgers University

I speak in three distinct capacities: first, as a former department chair, then as a member for many years of a university committee concerned with priorities in research and graduate education, and finally as the director of the new NSF Science and Technology Center in Discrete Mathematics and Theoretical Computer Science (DIMACS).

Let me say first that I have found that, given any reasonable expectation of success, mathematicians are sufficiently self-motivated to apply for individual research grants. However, especially but not exclusively, the problem is rather the preparation of an effective research proposal. As chair, I wrote up a detailed set of guidelines. I then critically read drafts of the proposals of junior faculty (and any senior faculty who asked for my opinion). On a number of occasions, I got the faculty member to give me a lecture about the proposal so that I could determine what he/she was really after. I like to think that in at least a few cases, my help made the difference between being funded or not. This job need not be limited to the chair, but could be assigned to any experienced grant-getter in the department.

In my committee member role, I looked for ways of increasing faculty incentives to apply for grants. As I said, this is not so important in mathematics with respect to individual grants, but is important in other fields, especially the experimental sciences, and also in interdisciplinary or unusual types of grants. Rutgers instituted a policy of a return of a percentage of overhead to the department. This gave departments a strong interest in having their faculty seek outside funding. Other areas where the committee affected university policy on research grants included (a) the total percentage of allowable summer salary (up to 3/9 for someone having more than one grant), (b) reduced teaching for faculty with academic year support, (c) tuition remission for graduate students, and (d) reduction in university overhead rates (included as part of the university cost-sharing) in connection with unusual grants that often have programmatic funding limitations.

My own feeling is that, in the end, such incentives normally play only a marginal role in who seeks external funding and who gets support. In most cases, the inner drive of the faculty member and the merit of the proposal itself are the dominant factors.

We come now to extraordinary type grants. Certainly the grant to DIMACS (as our center is called) falls in this category. I can describe how the center works in any amount of detail you would like to hear, but in these comments I would prefer to focus on what was involved in putting together a successful proposal. It goes without saying that without the existing scientific strength in the four participating institutions—Rutgers, Princeton, Bell Labs, and Bellcore—no amount of effort would have availed. But with only 11 centers funded out of 322 proposals received, this was a necessary but far from sufficient condition for success.

The NSF solicitation request stressed four things:

1. Proposed centers should be primarily research-oriented.
2. It should involve university-industrial cooperation to strengthen U.S. competitiveness.
3. The proposal should include a significant educational component.
4. It should also include a "knowledge transfer" component to ensure that the fruits of the center's research be widely disseminated.

I have no doubt that the ultimate success of the Rutgers proposal was in part a result of the considerable effort made to meet these requirements: first, by involving both Bell Labs and Bellcore as participating institutions along with Princeton and Rutgers; second, by designing research programs that struck a balance between basic research and possible industrial applications; and third, by including in our educational component two pre-college programs of foundational material: one for high school mathematics teachers, the other for high school students with mathematical ability and interest.

Now comes the task of turning this written proposal into a living reality. With four distinct partners, each in its own geographical location and each with its own rules of operations and organization (and with the Center's independent office space still a few months off), this has not been easy to achieve. Nevertheless, even though we have been in full operation for only a very short period, I believe we are on our way to implementing the proposal effectively.

ADDENDUM: PREPARATION OF NSF PROPOSALS

Over the years, I have had a lot of dealings with NSF proposals. At first, I was primarily a reviewer, but in recent years, I have helped some of the junior faculty with the preparation of their proposals. This was done more or less on an ad hoc basis—someone would ask me to look over a proposal, and I would make some suggestions for improving it. Or I would go over referees' reports with someone who did not get funded the previous year to see if the criticisms that were leveled against the last proposal could be avoided this time around.

This year I decided to be a little more systematic about it, and I have just read through all proposals from junior faculty who either were not funded last year or are new members of our department, with a view to helping them improve their proposals. (I would be happy to do the same for any senior faculty member, but feel it is out of place for me to do that on my own initiative.)

I have been struck all along by the uniformity of criticism which I tend to make of the proposals I read. It therefore seems a good idea for me to detail some of the general ideas that I have about NSF proposals and the NSF itself. That is the purpose of this memorandum. Perhaps these comments will be useful to senior faculty as well, and so I am distributing them to the department as a whole for whatever it is worth.

1. Quality of the proposal versus quality of the individual

I believe mathematicians have a misconception about the weight that the NSF assigns to the quality of the actual proposal that is submitted. I know many whose proposals are only a page long—sometimes less—just a bare statement of the problems. The assumption is that they are really "good enough" mathematicians to get funded if they simply sign their names to the proposal. The fact is that this is true in many cases; but it primarily applies to outstanding, well-established mathematicians.

An individual who falls only slightly below this level puts himself/herself in jeopardy by submitting such a proposal. Once a referee criticizes an actual proposal, even if he says fine things about the person, it makes it much more difficult to get funded. As far as I can tell, the NSF goes only on the basis of its referee's reports; that is the sole criterion it uses (at least officially) in reaching its decisions. Having had many one-page and one-paragraph proposals to review over the years, I can assure you that it is often a strain on the reviewer to evaluate such a proposal. One has to guess what was in the proposer's mind, and many times the reviewer is unwilling to make that guess the same way as the proposer. I know specific cases of leading mathematicians whose proposals were criticized and, as a result, were not funded.

Short proposals often suffer from vagueness. Without sufficient detail, it is not always clear what the proposer really has in mind. The proposer very often leaves out essential aspects of the proposal, assuming that they are implicit in what he has written, whereas, in fact, a common criticism by NSF reviewers is that a proposal is "vague."

If one will contrast what goes on in other fields, one will see at once the difference in attitudes toward proposal preparation. I know many cases where the preparation of the proposal takes a month, or longer, of really hard work on the part of the proposer.

The NSF has just issued new guidelines on lengths of proposals: a maximum of 15 pages. Presumably they had been getting proposals of 75 pages or even longer; but 15 pages is not the same as 1 page! For a junior faculty member, these comments are important.

Of course, don't get the idea from this that individuals are not also judged by reviewers. Certainly a reviewer may comment on someone's abilities, past accomplishments, or lack thereof, sometimes favorably, other times very harshly. But this is something over which one has no control. It is not clear how anything one puts into a specific proposal can influence a reviewer's judgment of an individual's stature in the field.

2. Significance of the proposal

Most of the "junior" proposals I have read make little or no attempt to put the problems in any kind of general context and rarely indicate the impact of a positive (or partial) solution on other problems. It is just taken for granted that the reviewer, being an expert in the field, understands all this, and will assume that the *proposer* does as well. Hence it is presumptuous—perhaps even patronizing—for the proposer to elaborate the full significance of the problem area. But the reality is the exact opposite—the reviewer, in general, will not make any such assumption about what the proposer knows, particularly if he doesn't know the proposer at all, and maybe even if he does. Another problem is that the reviewer may well have a totally different opinion as to what is "significant" than the proposer has. Maybe no matter what the proposer writes, the reviewer will not regard it as an important problem (and perhaps he'll be right), but if the proposer makes a strong case as to why he's planning to work on this particular problem, he may influence (or at least temper) the reviewer's judgment of its significance. Believe me, for a reviewer to write that "this problem is not very significant" is usually the kiss of death.

In applied mathematics, especially in interdisciplinary areas, the difficulties are compounded, for one can't even go on the assumption that the reviewer is, in fact, an expert in the field. NSF has much more trouble finding appropriate referees in such areas than in well-established clear-cut fields such as "classical harmonic analysis" or "group theory." So a great deal of thought has to go into this aspect of the proposal. In this connection, it is possible for a proposer to suggest to the NSF a list of potential reviewers.

3. The likelihood of success

I find that this represents one of the weakest parts of the proposals I read. Many individuals content themselves with a precise statement of the problems to be attacked and the results obtained so far toward their solution. That is appropriate for a paper, but totally off the mark for an NSF proposal. Well, I should modify this. If one has a reasonably substantial record of having solved problems in the past, it may be entirely sufficient to write the proposal in this way. The referee will most likely assume that the individual has the capability of solving the problem, or at least obtaining something worthwhile on it. But again, one is taking a gamble. I know specific cases in my own field in which the reviewers, despite the clear significance of the problems, were unable to decide from the proposal whether the individuals had any *ideas* as to how to solve them. These were middle-level junior people of very high ability, but they did not get funded. It is easy to propose to work on the Riemann hypothesis, but I guarantee that despite its significance, not many of us would get funded in that direction!

I think that an essential ingredient of any proposal (especially for junior faculty) is to explain in some intuitive way what one has in mind. I know that mathematicians, being such an honest group, are reluctant to make claims about what might or might not work on a given problem. But it's not a question of learning how to "exaggerate." What is required here is an explanation of the techniques you plan to use, why you think they have a chance of working, including special cases that you may have solved, examples that you may have worked out already, partial results you may already have obtained, etc.

One component of a reviewer's evaluation will almost certainly be his judgment of the proposer's chance of success. Moreover, the question of "success" is extremely important to the NSF. In examining how the NSF goes about justifying *its* funding from Congress, one will discover a very detailed discussion (in general terms, of course, for Congress) of specific problems that have been solved on NSF grants. For example, last year's mathematics request to Congress referred specifically to Sims and Leon's construction of the "baby monster."

4. Summary

A good proposal should include the following items:

a. Sufficient detail,
b. The significance of the project, and
c. Justification for thinking problems can be solved.

DEVELOPMENT GRANTS

Calvin C. Moore
University of California

Based on experiences at the Mathematical Sciences Research Institute at Berkeley and in university administration as a vice president, I would like to share with you some ideas about funding opportunities and strategies. But first I will discuss the general situation in our profession.

Ph.D. production in the mathematical sciences in the United States has declined steadily to approximately 750 per year. The most alarming part of this number is that half of these degrees are being earned by students who are not U.S. citizens. There is a general view that we are not renewing the profession at the necessary rate. We cannot continue to rely on foreign students because of the increasing opportunities these students will have as opportunities and funding for research increase in their home countries. Currently, we are able to induce a large number of these students to remain here and contribute to the profession.

I am happy to say that the most recent data indicate at least a bottoming out of the decrease in the proportion of U.S. mathematical sciences Ph.D. degrees earned by U.S. citizens. Perhaps this is the beginning of a turnabout. However, we have a very serious problem.

There is a need to renew the profession, not only in the mathematical sciences, but in all disciplines. For example, the University of California, all campuses, will need to hire 10,200 faculty in the next 16 years. The recent book by Bowen and Sosa, *Prospects for Faculty in the Arts and Sciences*,[1] paints a similar picture nationwide. Additionally, the NSF has projections of the doubling of the need for terminal degree holders in science and engineering. The NSF also projects that the current level of production will fall short by a factor of 50 percent. The report *Workforce 2000*[2] indicates that of the total additions to the work force through the year 2000, only 15 percent will be white males. This has enormous implications. It means that we will have to capitalize on the talents of women and minorities to a far greater degree than before. In the past one spoke of affirmative action programs as a rationale based on social justice. Now the rationale is much wider; it is a matter of survival.

In brief, I am sketching a human resource problem of major proportions that must be addressed at all levels, from kindergarten through postdoctoral years. Given this situation, there are excellent opportunities for funding. I would like to suggest to you a certain type of proposal that has certain analogies with the mathematics institute proposal. I call these, for lack of a better term, development grants.

This kind of proposal would have a number of components, including graduate student support, postdoctoral support, and considerable attention to undergraduate programs to increase the flow of students into graduate school. Also, special attention would be given to enhancing the participation of women and minorities. The most important component is a well-thought-out plan. In other words, the proposal would be for a type of mathematics institute within a department.

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[1] Bowen, W.G., and J.A. Sosa, *Prospects for Faculty in the Arts and Sciences* (Princeton University Press, Princeton, N.J., 1989).

[2] Johnston, W.B., and A.E. Packer, *Workforce 2000—Work and Workers for the 21st Century* (Hudson Institute, Indianapolis, Ind., June 1987).

Recall that the mathematics institutes have as one of their primary missions the training of postdoctoral fellows, that is, providing a research experience for them in a rich atmosphere of senior investigators and a flow of ideas that would enhance their career potential. That is a human resource program at the postdoctoral level. The proposals I am discussing would be for human resource development at all levels. Precedents for this exist in the National Science Foundation, in the Computer Sciences Division and in the Biological and Behavioral Sciences Division. The prospects for the funding of such proposals are enhanced if the application clearly states the kinds of resources the department is willing to contribute to the project.

These grants address human resource issues. My reading is that such proposals would resonate with current thinking in the federal government, especially at the NSF. According to Dr. Judith Sunley, there is a set-aside in the Division of Mathematical Sciences of the NSF for proposals that address increasing the participation of women and minorities.

The NSF has proposed to issue a rather remarkable document, *Important Notice 107*. This notice adds requirements to ordinary grant proposals. Specifically, each proposal must include a statement specifying the potential of the proposed research to contribute to the education and development of human resources in science and engineering at the postdoctoral, graduate, and undergraduate levels. This statement may include, but is not limited to, the role of the research in student training, course preparation, and seminars, particularly for undergraduates. Special effectiveness or achievement in the area of producing professional scientists and engineers from groups currently underrepresented should be described.

This statement is set forth in a document that applies to all proposals submitted to the NSF after it becomes effective. It is a clear signal of a change in the reward structure. It addresses a problem that was discussed earlier today: How do we convince faculty to devote their energies to issues that go beyond research and include human resource development? The NSF has taken an important step. Research proposals are required to address these issues and combine them with research.

QUESTION-AND-ANSWER SESSION

PARTICIPANT: I noticed that two of you mentioned the fact that our graduate students are the best means of technological transfer. I would like to amend that. They should be, but they are not. It is clear that we have the best research establishment in mathematical sciences in the world; yet we have one of the poorest technological transfer establishments in the world. I suggest, as a possible solution to this, that a portion of the graduate programs in mathematical sciences should be changed to address that issue.

DR. GLIMM: Graduate students are the best means of technology transfer if they are transferred. However, in many cases they pursue academic careers. I think you are raising the following questions: Should our graduate education be broader? Should we expect a certain fraction of our students to have industrial laboratory careers and an appropriate education? Affirmative answers to these questions would assure that the technology would be transferred through those students. Perhaps we were neglecting that kind of employment consideration in designing our programs.

DR. GORENSTEIN: For a certain percentage of students, that is very appropriate. Maybe we have neglected it. But there is still core mathematics. The best way to train people for that is to let them prove theorems. I don't know the proper balance.

PARTICIPANT: Technology transfer has happened more in statistics than in core mathematics. One of the reasons is that, historically, statistics has recruited into graduate programs students with undergraduate careers in application areas. These persons pursue careers in industry and government more than mathematicians do. It is not easy for statistics to recruit these people; I am sure it is more difficult for mathematics to achieve, but that appears to be a source of technology transfer people.

PARTICIPANT: I was struck by Dr. Gorenstein's comment about departments at Rutgers getting a return of indirect costs. I have the task of trying to elevate the level of funding in my department. I am curious as to what fraction of indirect costs comes back to a typical mathematics department.

PARTICIPANT: About 5 percent.

PARTICIPANT: The University of Maryland gives back 25 percent.

DR. GLIMM: In addition to the routine recovery, I think unusual situations sometimes allow for a larger recovery.

PARTICIPANT: Just a comment to follow up—that is not the sole measure of how well a department does. Many universities reward departments that bring in a lot of money in other ways. They may increase their basic budgets, for example. We get 30 percent return, but our basic budget is about one-quarter or less of what we need to operate. So it is just a matter of how the money is passed to the department.

DR. GORENSTEIN: Princeton University gives back zero. However, from my experience, the computer science department is treated very well at Princeton. Every faculty member has a secretary. So one must examine the way in which a university operates vis-à-vis the department.

PARTICIPANT: I know that in hiring senior faculty members, particularly in the physical sciences, it is becoming more common for administrations to agree to return a fraction of grant overhead generated by that person as start-up costs. It seems to me that if one is hiring a very strong faculty member in mathematics, one could get the same kind of agreement for start-up costs from the dean that the physics chair is getting for his people.

DR. MOORE: The issue of start-up costs is a concern from the perspective of provosts and vice presidents. It is, on average, $100,000. That is averaged over all fields, including the humanities. For senior people in the physical sciences, it can go as high as $1 million. This is a form of subsidy to those departments. You are quite right that mathematics departments have not entered into the sweepstakes to the degree that they might.

4 PLENARY DISCUSSION

Panelists assembled to take questions from the floor and respond to any written questions received after the Friday sessions.

PLENARY DISCUSSION

Phillip A. Griffiths (Presider), Duke University

Ronald G. Douglas, State University of New York, Stony Brook
Frank C. Hoppensteadt, Michigan State University
Gerald J. Lieberman, Stanford University
James Glimm, State University of New York, Stony Brook
Daniel Gorenstein, Rutgers University

PLENARY DISCUSSION

Phillip A. Griffiths (Presider)
Duke University

DR. GRIFFITHS: Each of us has selected and will respond to some of your written questions. When all responses to written questions have been completed, if time permits, we will respond to questions arising from the responses.

QUESTION: Could the concerns of those of us from smaller, lesser known institutions be addressed by this body?

DR. GRIFFITHS: That is a very good question. We are now beginning to plan next year's colloquium. A topic centered around this issue would be very appropriate. It would help if you can be more specific about the problems and issues you would like to see addressed in such a session and communicate them to Dr. Cox.

QUESTION: What kind of mathematician, research or nonresearch, makes a better chairman?

DR. GRIFFITHS: First, issues of character, judgment, and interpersonal skills are important in the effectiveness of a chairman. So the question has to be understood as assuming these things. Now, a successful chairman has to understand the field of mathematics and have the respect of his colleagues. Because of the culture of our field, this may be easier for someone who has an established research career, although he may no longer be active. That does not mean that this is either a necessary or a sufficient condition. In general I would say it is helpful. Also, the job of chairman is sufficiently complicated now that it is very difficult to do it well in spare time.

QUESTION: How does one get an administration to keep its promises to upgrade a poor department?

DR. GRIFFITHS: This is obviously going to vary from institution to institution. Most institutions with which I am familiar operate in a rather formal manner. My job as provost is to recruit and work with deans. First, there are negotiations. Then, a written document is presented in which I state the institution's commitment to the dean over the next three to five years—essentially, financial arrangements. The same thing should occur between deans and chairs. There should be a clear written understanding between the dean and the applicant before the chairman accepts the position. There will always be a caveat concerning maintaining current conditions because we are all subject to the vagaries of the federal government, state governments, donors, and so forth.

QUESTION: Is the declining pool of employables an argument for more money?

DR. GRIFFITHS: This will be one of the major themes of the update of the David report, which will be discussed at length this afternoon. The discussions of that committee have made several points. First, the field of mathematics is intellectually attractive. It is becoming even more so as mathematicians become involved in problems from the other sciences. Second, in contrast to some years ago, there are now open teaching positions, and more are projected to open in the coming years. So there are job opportunities in academe as well as industry and the national laboratories. Given those conditions, we ought to be attracting more talented students. Part of the discussion in the David committee is that the mathematics community itself needs to try to recruit more systematically into the field. The report will contain suggestions as to how this might be done.

QUESTION: Are there ongoing studies on the demographics of the current population of undergraduates in mathematics that can tell us if we will have enough American graduate students from minority or majority groups in the coming years?

DR. DOUGLAS: One of the things coming out of the MS 2000 project will probably be a great deal of statistics. The numbers are somewhat ominous. There is a large number of undergraduate majors, but not as many as there were in the 1960s. The number has gone up somewhat in the last few years. Still, most studies indicate that we need more students in mathematics. Between the David report update and MS 2000, the mathematics community will be provided a great deal of information. It is up to us to use it as best we can, both for our own planning and for convincing others.

QUESTION: How does one persuade deans to provide maintenance personnel for computer hardware and software?

DR. DOUGLAS: One possibility is to suggest the use of half a faculty line for this purpose. However, that kind of staffing is a little different from ordinary faculty. So, it depends on one's department and its needs.

QUESTION: How can we get more students into mathematics if we don't have good introductory courses that show them what mathematicians do?

DR. DOUGLAS: That is a complicated question. It is a concern not just in mathematics but in other sciences as well. A large percentage of the people who come into a university or a college do take mathematics courses. From that point of view, we are the envy of most other disciplines.

QUESTION: Dr. Hoppensteadt mentioned that chemistry and physics departments have strong industrial contacts. Do you see those same individuals as potential benefactors of mathematics departments?

DR. HOPPENSTEADT: Yes, I do see them as benefactors to mathematics departments. They want the people they hire to have mathematics skills. However, they may not be a source of money for mathematics departments. That is primarily because the money they give to departments is sharply directed toward specific applications. Note that money is not the only consideration in building friends for your department. These people provide a channel to the central administration. Also, they can give insights into the kind of competitive market we are facing. We are facing an incredible gradient in salaries. For example, a student graduating with an MBA and going into a top-of-the-line brokerage will start at $75,000 and be guaranteed $150,000 after four years. If successful there, one can go to approximately $500,000. Success at that level means the sky is the limit. So the gradients we are facing are steep. We can get support for that from industry. By building a group of users in industry, one creates a network of hiring for students. This also provides good information about the salary structure in industry.

QUESTION: To what extent, if any, should a dean be able to dictate to a mathematics department the research field in which an open position is to be filled?

DR. HOPPENSTEADT: My view of administrators is that our first duty is to keep administration out of the way of the faculty. If there is a confrontation with a dean over a position, there could be serious problems. The position might not be filled, or a new position could suddenly appear in some other department of the university. To avoid confrontation there should be consultation within the department. Create a consensus within the department. Most importantly, develop a plan for the department. The administration may not sign off on it, but a plan opens the door to negotiation with the administration.

QUESTION: When is it proper for a chair to go over the head of a dean to a provost to get the dean's decision overruled?

DR. LIEBERMAN: It is always appropriate for the chair to go over the head of a dean, provided that the chair has informed the dean of those intentions. Now, having said that, let me say what I really think. Going over the head of a dean is a terrible mistake. One must understand that, essentially, a dean serves at the pleasure of the provost. If the chair goes to the provost, the first thing the provost is going to do is talk to the dean. This is really a no-win situation for everyone. One would like to feel that a chair can cooperate with a dean. However, it may be that the dean is not sympathetic to the needs of mathematics. But there are other ways of voicing these problems that can get to the provost's ear. For example, there are budget letters that go to the dean. I presume that most provosts will be made aware of the desires of the department.

QUESTION: Does the panel endorse Professor Reed's suggestions that faculty whose scholarship is failing or has failed be given dominant responsibility in the teaching program?

DR. LIEBERMAN: I do not agree in general that faculty whose scholarship is failing or has failed be given dominant responsibility in the teaching program. Teaching, research, and scholarship are so intertwined that one could question whether or not the failure of scholarship also indicates a failure of interest, or a failure in teaching ability. It has been my experience that people who are relatively poor in scholarship are probably not very good at teaching. However, there are outstanding teachers who are not great researchers. If they have the managerial talents required to lead a program, then, in certain instances, it may not be unreasonable to do that. This may be a way of utilizing much-needed talent, because the teaching of mathematics is an important issue. It is, also, one on which departments are frequently under fire. I cannot give an off-hand response of yes or no. One has to examine individual circumstances.

QUESTION: Where can one get national data on teaching load, class size, travel support, levels of computer support, and levels of secretarial support for mathematics departments?

DR. GLIMM: Data will be available from the David II report and *A Challenge of Numbers*.[1] Perhaps some of those details will not be determined. Someone should try to assemble that data.

QUESTION: What can a mathematics department do to demonstrate to the administration that it is strongly interested in undergraduate teaching?

DR. GLIMM: The answer to that question is "by doing it." I want to elaborate on that. Having recently come

[1] National Research Council, *A Challenge of Numbers: People in the Mathematical Sciences* (National Academy Press, Washington, D.C., April 1990).

to Stony Brook, I looked over the facts there and discovered, to my pleasant surprise, that their record in teaching is excellent. That is borne out in the statistics. Their fraction of the undergraduate students may be three or four times the national average for undergraduates as a fraction of the total student body of the university. Their total contribution to the national pool of mathematics majors is a respectable percentage. St. Olaf College also has an incredible percentage of mathematics majors. The answer is in caring about the students. It is part of the culture in those departments that the teachers care about the students and that the faculty care about that fact. From informal discussion, I know that people value the research of their colleagues; they also value the teaching performance of their colleagues. Caring about students involves such things as noticing when a student is in trouble and initiating a conference. At a higher level, which is the department chair's charge, or the charge of the senior people in the department, it is to communicate to all the instructors the standard of caring the department expects of its teachers. For example, part of the teaching evaluation lies in the ability to teach a large course. Even better is the ability to create a course with large enrollment, in other words, to find the students and bring them into the department.

QUESTION: What are typical start-up costs for hiring mathematicians that are accepted by administrations?

DR. GLIMM: That is extremely variable. Probably the most common is zero. The question probably refers to cases where start-up costs are allowed. For people who are doing computing, it could include computer equipment. For distinguished individuals, it could include a secondary appointment. Also, there might be research support during a time when grants are being transferred. It could include temporary support for visitors, or include a focus that could lead to a special year centered around the research interests of the person being hired.

DR. GORENSTEIN: The start-up cost is usually zero. However, there are circumstances under which an administration will respond and produce funds for start-up costs. A small research stipend in mathematics goes a long way. For $10,000 one can practically run a conference or bring in visitors. The important point is that it is not always zero. One has to make the case.

QUESTION: I would like to hear comments on the following statement our dean offered us about four months ago: "Mathematicians can teach more efficiently than anyone else in the sciences, and so it is natural that the student-faculty ratio is higher in mathematics than in any other science."

DR. HOPPENSTEADT: I do not think it is effective to try to fight on the basis of student credit hours. One should view student credit hours as a strength of the department and not as something that is being inflicted on the department. The more a department can get in with the program of the university, the better the department is going to succeed. At Michigan State, the mathematics department deals with 10,000 students per term. That is a staggering number. One could hit people over the head with the number, but it would accomplish nothing.

PARTICIPANT: May I follow up on that question? When I was chairperson I found that numbers were somewhat effective, provided they were presented in a context administrators could understand. The college marvelled at how interesting it was that every calculus section contained 75 students. The AMS published data indicating that nationally, the average section size was approximately 40. I used the educational quality argument with my dean. I did not say our quality was hurt because we had so many students. I said we needed new resources because we should at least be able to educate mathematics students the way it is done nationally. The administration agreed to that.

QUESTION: We have always taught calculus in sections of about 25 or 30. Is it better to have an outstandingly motivational person, someone active in research, teach 150 or 200 students? Would this increase student understanding of mathematics, or would it sharply decrease it?

DR. HOPPENSTEADT: It is amazing that those kinds of things are not known. An experiment was conducted at the University of Wisconsin in the middle 1960s. The same examination was given to large lectures and small sections. One could not distinguish between results on the examinations. So it is surprising to me that we have not done more to investigate these kinds of issues.

PARTICIPANT: Formerly, we taught calculus in large sections only. We told the administration that the norm for calculus was much lower. We were allowed to cap all of our majors' calculus courses at 35. As a result the failure rate for all sections went down.

DR. DOUGLAS: When we consider the question of small sections versus large sections, I am not sure that all of the relevant variables are taken into account. Also, I am not sure whether studies from the 1960s would carry over to the students of the 1990s. The difference between teaching students in small sections versus large sections is that one can do many things in a class of 30 that one cannot in a class of 100 or 150.

QUESTION: This concerns the question of the calculus initiative. I am under some pressure to go to a lecture format for calculus. On the other hand, there is also pressure to introduce the computer into calculus courses. Somehow those seem to be contradictory. Can you offer any advice?

DR. DOUGLAS: I am not sure there is an absolute answer to that. It depends on the resources one has. For example, at a liberal arts college where all teaching is done by faculty, it makes sense to teach calculus in small sections. In a university where there are teaching assistants, one must consider the competence of these TAs. The model one chooses depends on the personnel available. As for the question, I am not sure I see the incompatibility of having lectures and recitations versus experimentation.

PARTICIPANT: The computer is more labor intensive. If a calculus section is in a laboratory with 40 or 45 microcomputers, then an instructor can only service approximately 30 or 35 students during an hour.

DR. DOUGLAS: But there are other models. It is not required that every meeting of a calculus class, which meets three or four times a week, involve mathematics or involve the computer. One model is to have lectures and separate the class into smaller groups for the computer portion of the course.

QUESTION: Much of our attention must be focused on pre-calculus. Will someone address this problem?

DR. DOUGLAS: It is a national trend. The data show that approximately 50 percent of the mathematics classes are pre-calculus and below. If we are going to attract more students into mathematics, we not only have to teach the courses you are talking about; somehow we must make it possible for these students to take more mathematics.

DR. HOPPENSTEADT: I do not see that as a problem. I am sure that a significant proportion of the people in this room did not start with calculus in their first year of undergraduate school. A number took college algebra and analytic geometry or an equivalent course in their freshman year. That model has changed. There is an attitude that one must begin with calculus. I disagree. Certainly, for well-prepared students, the farther they get along in their undergraduate career the better. However, if it sets them up for failure later, they will not have been done a service. Another aspect is that arts and letters is a separate college. Some of them are requiring mathematics for all graduates. That is pre-calculus mathematics. They feel that mathematics is something their students should know. I don't see that as a problem. It is an opportunity for more resources. If that is what the administration wants to do and they support it, it gives us an opportunity to get more resources for our departments.

5 FEDERAL AGENCIES FORUM

Representatives of federal agencies that fund mathematical sciences research and education projects discuss and answer questions on their programs.

NATIONAL SCIENCE FOUNDATION
Carroll Wilde, Directorate for Science and Engineering Education

ARMY RESEARCH OFFICE
Jagdish Chandra, Mathematical Sciences Division

OFFICE OF NAVAL RESEARCH
Neil L. Gerr, Mathematical Sciences Division

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Charles J. Holland, Mathematical and Information Sciences

NATIONAL SECURITY AGENCY
Marvin C. Wunderlich, Mathematical Sciences Program

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Louis Auslander, Applied and Computational Mathematics Program

DEPARTMENT OF ENERGY
Donald Austin, Office of Energy Research

NATIONAL SCIENCE FOUNDATION
Judith S. Sunley, Division of Mathematical Sciences

NATIONAL SCIENCE FOUNDATION

Caroll Wilde[*]
Directorate for Science and Engineering Education

My task is to represent the Directorate for Science and Engineering Education of the National Science Foundation. This directorate is primarily concerned with education. Our focus is in mathematics education from kindergarten through undergraduate.

The Directorate for Science and Engineering Education (SEE) is composed of the following units:

Division of Teacher Preparation and Enhancement (TPE)
Division of Materials Development, Research, and Informal Science Education (MDRI)
Division of Undergraduate Science, Engineering, and Mathematics Education (USEME)
Division of Research Career Development (RCD)
Office of Studies and Program Assessment (OSPA)

The approximate levels of funding are as follows:

	FY 1989 Plan	FY 1990 Request
TPE	$63.5 M	$68.5 M
MDRI	44	49
USEME	28	30
RCD	31	38
OSPA	4.5	4.5
TOTAL	$171.0 M	$190.0 M

The following is a list of mathematics contacts in SEE:

MDRI	Thomas Berger	(202) 357–7066
USEME	John S. Bradley	(202) 357–7051
TPE	Glenda Lappan	(202) 357–7069
	Charles Eilber	(202) 357–7751
	Joan Ferrini-Mundy	(202) 357–7074
	Carroll Wilde	(202) 357–9527

[*] SEE/DTPE, Room 635-B, 1800 G Street, NW, Washington, DC 20550. Telephone: (202) 357-7074.

ARMY RESEARCH OFFICE

*Jagdish Chandra**
Mathematical Sciences Division

There are three sources of support in mathematical sciences from the Army Research Office. The first is our core program involving individual investigators. Second are the Centers of Excellence, now numbering three. These centers offer a wide spectrum of opportunities through a visitors program and an extensive program of support for predoctoral and postdoctoral fellowships. A third source of funding is through the Innovative Sciences and Technology Program sponsored by the Strategic Defense Initiative Office (SDIO). This is also for individual investigators.

One issue that concerns us is the growing erosion of support for individual investigators. The ratio of individual investigators' support to center support has become very unhealthy. Although this is not limited to mathematical sciences, it is particularly acute in this field.

We view the centers as national resources. The facilities and the opportunities at these centers should not be limited to the home institutions. I do not think at this point that these centers are being used in an optimal way. I remind you that a significant amount of support at these centers goes to visitors, graduate students, and postdoctoral fellowships.

These centers have different emphases and foci. For instance, the recently established center at the University of Minnesota is primarily concerned with issues in high-performance computing. As such, the emphasis at the other centers is on other aspects of mathematical sciences. For example, the Mathematical Sciences Institute at Cornell has placed major emphasis on analysis, probability and stochastic processes, and physical mathematics. There is also a growing interest in geometric analysis at this center. It will be competed for renewal during the fall of 1990.

In summary, we seek stable funding, for individuals as well as for multi-investigator centers. There are many impediments to accomplishing these goals. There are always attempts to create new programs without any thought given to stability of the programs. Funding is tight all around. However, you will have no opportunity for support unless you get into the competition. We are willing to talk.

* P.O. Box 12211, Research Triangle, NC 27709. Telephone: (919) 549-0641. E-Mail: chandra@brl.arpa

OFFICE OF NAVAL RESEARCH

Neil L. Gerr[*]
Mathematical Sciences Division

There have been some changes at the Office of Naval Research (ONR). The biggest changes have been in personnel. We have two new people, John Lavery in applied analysis and Marc Lipman in discrete mathematics. Richard Lau, in numerical analysis, has been with ONR for approximately 15 years. Julia Abrahams is running the probability and statistics program and is also the acting scientific officer for operations research. We are now interviewing candidates for operations research.

I am acting as scientific officer for signal analysis. That is another position for which we are interviewing candidates.

The other big news concerns our new FY 1991 research initiatives, which we competed for last year and succeeded in having authorized by upper management. We are currently working on 1992. There is not much I can tell you about that today.

The first FY 1991 initiative, random fields for oceanographic modeling, is joint with ocean atmospheric sciences and is being managed by Julia Abrahams. The goal is to develop random field models, which are based on physical models, particularly, physical models as might apply to oceanography.

I will manage bioacoustic signal classification. It is a joint program with cognitive and neural sciences. The idea is to try to use knowledge of neurophysiology and psycho-acoustics and the way mammalian organisms process acoustic signals to develop new signal processing techniques for use by the Navy in sonar.

Finally, Richard Lau, in numerical analysis, will sponsor some new work in computational microwave scattering.

Mathematical Sciences Division personnel and telephone numbers are as follows:

Applied Analysis	John Lavery	(202) 696-4314
Discrete Mathematics	Marc Lipman	(202) 696-4310
Numerical Analysis	Richard Lau	(202) 696-4316
Operations Research	Julia Abrahams	(202) 696-4320
Probability/Statistics	Julia Abrahams	(202) 696-4320

[*] Code 1111, 800 N. Quincy Street, Arlington, VA 22217. Telephone: (202) 696-4321.

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

*Charles J. Holland**
Mathematics and Information Sciences Directorate

There are six directorates at the Air Force Office of Scientific Research (AFOSR). Mathematics and computer science are combined and represent the Mathematics and Information Sciences Directorate. Unlike the other services, we manage all basic research activities, including the work at the laboratories. So we divide our funding as appropriate between universities, industries, and the Air Force laboratories.

Within this directorate, program areas and their managers are as follows:

Applied Mathematics	Arje Nachman	(202) 767-4939
Control Theory	Marc Jacobs	(202) 767-5025
Optimization and Discrete Math	Neal Glassman	(202) 767-5026
Computational Mathematics	Arje Nachman Charles Holland	(202) 767-4939 (202) 767-5025
Probability, Statistics, and Signal Processing	Jon Sjogren	(202) 767-4940
Artificial Intelligence	Abe Waksman	(202) 767-5027
Computer Science	Charles Holland	(202) 767-5025

Our preferred strategy for receiving proposals is that first you call the appropriate program manager. Then send a small white paper describing your interest and a few publications, reprints, or preprints that document the direction in which you are heading. Let us tell you whether it is worth your time to send us a formal proposal. You, as chairmen, need to enforce this rule because we continue to receive 20 to 25 copies of proposals, sent at considerable university cost, that are not appropriate for our agency.

We spend our money early. Ideally, our goal is to have all of FY 1990 money committed already. We have about two-thirds of it already earmarked.

Another issue is that near-term funding is not growing within our organization. Still, the program is highly competitive. There is a substantial amount of turnover. Turnover occurs when new people come in and see new directions for a program and implement those directions. The only requirement is that they are valid scientifically and are likely to have substantial Air Force impact.

* AFOSR/NM, Bldg. 410, Room 203, Bolling AFB, DC 20332-6448. Telephone: (202) 767-5025. E-Mail: chollan@answc-wo.arpa

We have a defense research sciences program, which is approximately $20 million. It is advertised in the *Commerce Business Daily* once a year.

AFOSR has two University Research Initiatives (URI) programs: the standard large block program and a small geographically broadening initiative, which supports people who have not received a large amount of DoD funding in the past. Both of these programs were run last year. Three-year awards were made so they are not likely to be recompeted for at least two years. It is not likely that we will have an equipment program this year.

We support other programs. There is a summer faculty research program in which faculty join Air Force laboratories, find out what the laboratories are doing, and may get a small contract afterwards. Graduate students can also participate.

Also, AFOSR supports a high school apprenticeship program and two graduate fellowship programs. There is an Air Force graduate fellowship program and a graduate fellowship in conjunction with URI. The Air Force, the Navy, and the Army all agreed on one common application form. Look for the brochures.

Finally, we have a university resident research program and a postdoctoral program. So there are other opportunities in addition to those in the Mathematics and Information Sciences Directorate. Our *Research Interests* brochure describes all our programs.

NATIONAL SECURITY AGENCY

*Marvin C. Wunderlich**
Mathematical Sciences Program

The name of our program is NSA Mathematical Science Grants Program (NSAMSGP). I am the program director. I will discuss things in three parts. Since we are new in this activity, I will give you a brief introduction to the program. Then I will discuss our funding statistics over the past year or two. Finally, I will share with you information concerning our grant application process.

The program, then known as Outside Cryptologic-Related Research (OCREA), began in 1980. For approximately five years we funded only research in cryptology or cryptography. The grants were all reviewed internally by our agency. The budget was very small.

In 1987, General Odom, who was our director at the time, decided to expand the program and fund general mathematics rather than just cryptology. Now general mathematics receives over 90 percent of our funds.

Three changes occurred due to the David report: we greatly expanded; the name of our program was changed; and the peer panel external review system was instituted. Proposals in pure mathematics are not reviewed internally. They are sent to the National Research Council. We have a review panel and a review panel representative, John Tucker. The panel consists of ten mathematicians. Each member of the panel gets a certain segment of the proposals and then chooses four outside reviewers for each proposal. These reviews are received by the Board on Mathematical Sciences at the National Research Council. Once or twice a year the panel meets in Washington, D.C., and puts all the proposals that have been received into one competition. It is my job, then, to reflect that order when I fund grants with the available money.

The purpose of our program is to support American mathematical research and to increase the supply of U.S. citizen mathematicians, whom we employ in great numbers. Our current director, Vice Admiral William Studeman, strongly supports the program.

We support six areas: algebra, discrete mathematics, number theory, statistics, probability, and cryptography. The cryptography support is less than 10 percent of the total. Unlike other agencies, we have no mission relationship and no requirement that we know your interests in advance. Any good mathematics in an appropriate area will do.

I have no control over how much money goes to the various areas. The proposals are rated. I simply fund from the top down.

*Attention: RMA, Ft. George G. Meade, MD 20755-6000. Telephone: (301) 859-6438. E-Mail: mcw@mimsy.umd.edu

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Louis Auslander[*]
Applied and Computational Mathematics Program

The Defense Advanced Research Projects Agency (DARPA) is probably the newest of the funding agencies in mathematics. Maybe it is the strangest for everyone in the audience.

The perfect DARPA proposal involves the transfer of known mathematics to technologies of benefit to the Department of Defense. The benefits may be to increase military capabilities or to reduce the cost of production. Because of this, contracts must have yearly milestones and deliverables. Accordingly, funding after the completion of a contract is not contemplated unless new and exciting possibilities are again proposed.

Because of the nature of our mission, we have many joint academic/industrial contracts as well as industrial contracts. We bring together groups of people to work on projects and fund many interdisciplinary efforts involving mathematicians, physicists (theoretical and experimental), numerical analysts, and computer scientists. It is interesting that "old" mathematics can have a tremendous impact on our current technologies.

QUESTION: What kind of schedule are you operating on at DARPA?

DR. AUSLANDER: We take proposals at any time.

[*] 400 Wilson Boulevard, Arlington, VA 22209. Telephone: (202) 694-1303.

DEPARTMENT OF ENERGY

Donald Austin[*]
Office of Energy Research

The mathematics program of the Department of Energy (DoE) is within the Office of Energy Research. The budget of this office is more than $2 billion. The mathematical sciences, which includes computer science, has a nominal FY 1990 budget of $25 million. It covers all areas of mathematics, computer science, and statistics. Roughly half of the money goes to universities and half goes to the national research laboratories maintained by the Department of Energy.

It takes six months to process a proposal. We normally give three-year grants. They now range from $37,000 to $2.8 million. All of the programs are tightly coupled with mathematics and computer science at one or more of the national laboratories.

A few years ago, we started a geometry/topology program that looks very similar to the one the NSF is starting. These grants are in the $300,000 to $500,000 a year range. So, we occasionally begin new directions, but we do not do this with fancy brochures. We talk to people who have good ideas that seem to be feasible and related to the mission of the department.

QUESTION: I am at one of the places that has a laboratory. I was told by a program manager in the laboratory that since we have a laboratory, DoE would not be interested in proposals submitted by other units in the university. What is your feeling on that?

DR. AUSTIN: Are you a part of the university or just part of the laboratory?

QUESTION: Part of the university, but not part of the laboratory.

DR. AUSTIN: Then you are perfectly welcome to submit proposals to the DoE.

PARTICIPANT: There is considerable interest in the DoE with respect to education. Do you have any information on that?

DR. AUSTIN: Yes, I do. Last year we initiated seven or eight postdoctorals at the national laboratories. The purpose of these is to have more interplay between the laboratories and the universities. We also have an Office of University Programs led by Antoinette Joseph. She has a budget of $10 million to $15 million to support science education.

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[*] Washington, DC 20545. Telephone: (301) 353-5800. E-Mail: austin@lbl-csam.arpa

NATIONAL SCIENCE FOUNDATION

*Judith S. Sunley**
Division of Mathematical Sciences

You may have noticed that essentially all of us have avoided talking in any great detail about money. That is because we do not have a signed appropriation bill for FY 1990, which started on October 1. We are currently operating on a continuing resolution that expires next week.

I can tell you that the potential increase for the Division of Mathematical Sciences (DMS) in FY 1990 over FY 1989 is between 0 and 15 percent. Realistically, our maximal increase is probably on the order of 7 or 8 percent.

In FY 1989, having received an increase of approximately three percent, most of our individual research programs were effectively constant with the previous year in dollar terms. There were two programs that received the bulk of the increases. One was our Computational Mathematics Program, which was then in its third and basically its final year of building up to a sustainable level. The other was the Special Projects Program, where most of the increases went into the range of undergraduate activities that are found in the research directorates at the National Science Foundation (NSF).

The $30 million Dr. Wilde showed in the Undergraduate Science, Engineering, and Mathematics Division is matched by at least a comparable amount in the various research directorates. We are dealing with a variety of proposals, which are managed on a joint basis with the Science and Engineering Education Directorate.

Last year we produced and sent to every mathematics department in the country a brochure entitled *Opportunities in the Mathematical Sciences*. It dealt with both research and education. We did this because the *Guide to Programs* is very difficult to wade through if one doesn't have some focus. We have an updated version of the brochure, which is in the printing process. If you wish to have one, let us know and we will send a copy to you.

This brochure discusses a broad range of activities within the NSF in which mathematical scientists can participate. It is very important for you to look at it because frequently one focuses too closely on the Division of Mathematical Sciences.

One can examine the schedule of programming for this meeting and see the kinds of things that are emphasized. One is the education and human resources component. This is something to which the director of the Foundation is committed.

Important Notice 107, mentioned by Dr. Moore yesterday, is printed in full in this month's *Notices of the American Mathematical Society*. We have decided that because there were too many proposals already in process at the time information on the *Important Notice* was circulated, we would delay fully implementing its requirements until January 1. If you wish to add a supplementary education and human resources statement to an existing proposal, we will take it into consideration as we are making decisions.

The emphasis on education and human resources is having a big impact on the way we do business. It is difficult for the community to come to grips with the fact that the NSF has changed a great deal since 1980. The changes began with the initiation of the institutes, the development of the postdoctoral program, and the development of the equipment program in the late 1970s and early 1980s.

* Room 304, 1800 G Street, NW, Washington, DC 20550. Telephone: (202) 357-9669. E-Mail: jsunley@note.nsf.gov

The changes are continuing. It is important that the mathematics community become aware that the education and human resources component is becoming increasingly important. We consider it in the review and evaluation of proposals. It is not the overriding consideration. Research is still our business in the DMS. But these added components can help a proposal in an area where a hard decision must be made.

Another thing the NSF is emphasizing is instrumentation. Mathematics tends always to fall by the wayside when one talks of instrumentation. But I am convinced that this need not be the case. There is a great need in the mathematics community for adequate computer support of research efforts and education efforts. This is something chairmen should consider. That is, what are the needs for instrumentation in your departments, and in what way, if any, might we need to change the way in which we interact with you on instrumentation so that we can facilitate the development of strong instrumentation capabilities.

Another thing that has been changing in general is the portfolio of modes of support the NSF is presenting to you. I have already spoken of a few things in the DMS that one can see: the development of the institutes at Berkeley and Minnesota, the development of a postdoctoral research fellowship program, and the development of an equipment program.

We have begun other projects as well. Earlier speakers have referred to the Regional Geometry Institutes. This is the first DMS experiment at a real integration of education and research through similar projects or in the same project.

We have talked a great deal with the Science and Engineering Education Directorate. I urge you to call and talk to a program officer because we find that mathematicians and mathematical science departments do not compete as well as they might in the education arena. There is a way to write education proposals that are more likely to make it through panels.

The NSF has developed the Science and Technology Centers. The first round was funded less than a year ago. There is one center with "mathematics" in its title: The Center for Discrete Mathematics and Theoretical Computer Science at Rutgers. There are two others with significant mathematics components to them, one in parallel computation that is a joint center between Rice and Cal Tech. The other is a center on mesoscale storm systems at the University of Oklahoma. The Center on Microbial Ecology at Michigan State also involves mathematics very effectively.

The DMS has an activity designed to develop group research where appropriate. Too often a mathematics proposal to the NSF is viewed as a request for two months of summer support for one person. Indeed, at the NSF we have the lowest average grant size of any division. We are looking for projects that require group efforts and also the possibility of group efforts at training graduate students and postdoctorates.

We are also very concerned about underrepresented groups. A modest reserve is being held for people who have innovative approaches to encouraging the participation of minorities and women.

The division has done some split funding of certain kinds of activities with Science and Engineering Education in the Faculty Enhancement Program, the Young Scholars Program, and other areas. The aim is to foster the involvement of research mathematicians in education-oriented projects.

For those who are not in the statistics community, in an issue last spring of *Statistical Sciences*, a former program officer at the NSF had a lengthy article on the writing of an NSF proposal for young faculty. I commend this to your attention. It is an interesting and thorough explanation of what young people need to do in writing proposals.

QUESTION: The NSF has announced a program for small groups: Small Grants for Wild Ideas. Could you discuss that?

DR. SUNLEY: This program is called Small Grants for Exploratory Research. It is one of the responses to a study done in FY 1985 in which many people felt that innovative ideas were not getting through the peer review

system. The program was begun by the Engineering Directorate. It has recently been expanded to the entire NSF. I urge you to get the brochure.

DR. SUNLEY: You recall that in FY 1989 there was a cap of $95,000 for NSF supported salaries on grants. That cap has been reinstated in our FY 1990 appropriation bill.

6 MS 2000 UPDATE

A short status report on the Mathematical Sciences in the Year 2000 project, including a timetable for upcoming activities, is followed by some interesting information on human resources, curriculum, and support resources in the mathematical sciences, information that may be helpful to chairs in managing and securing department resources.

MS 2000 Update

James A. Voytuk, National Research Council

MS 2000 UPDATE

James A. Voytuk
National Research Council

My presentation is divided into three parts. First, I will give a review of the nature of the MS 2000 project. Then, I will preview the first report, which will be published soon. Finally, I will allow time for discussion to get your reaction to the information presented. Also, we would like to have your comments pertaining to the real concerns in higher education with respect to the mathematical sciences.

MS 2000 is a three-phase project. There is a description phase, a discussion phase, and a prescription phase. The description phase involves a national assessment of needs, resources, and opportunities in the mathematical sciences. In addition to assessing the human resources involved in the mathematical sciences, we are examining the undergraduate and graduate curricula in these sciences. Additionally, there will be a report on the resources that support the mathematical sciences: computing equipment, secretarial staff, library holdings, and so forth.

The discussion phase is designed to foster a national dialogue on issues that have an impact on mathematical sciences education. Meetings such as this and meetings of professional organizations concerned with the mathematical sciences provide opportunities to stimulate this dialogue.

The prescription phase will culminate in the publication of a report in 1990. The report will put forth an agenda for the renewal of college and university mathematical sciences education along with an implementation plan for those responsible for implementing the recommended changes.

Within the next 30 to 45 days we will publish our first report: *A Challenge of Numbers: People in the Mathematical Sciences*. It will be distributed to every mathematical sciences department in the country. Additional copies will be available for funding agencies, foundations, and the mathematical sciences community in general. In addition, there will be an executive summary of the report. Department chairs will receive extra copies of the summary, which may be passed along to higher administrators. Additional copies of the summary will be available for legislators on both the federal and state levels.

The report is a compilation of much of the data that currently exist on manpower, the workplace, salaries, and the scope of the educational process. Analysis of the data gives rise to two contradictory situations. The first is that there is an increasing need in the workplace for people with knowledge of collegiate mathematics. On the other hand, demographic changes and socioeconomic trends indicate that fewer students will study mathematics or pursue mathematics-based careers.

The increased need for a labor force that is more skilled in mathematics is evident from the following data summaries:

- Between 1986 and the year 2000, 21 million new jobs will be added to the U.S. economy, and more than 50 percent of these jobs will require collegiate study.
- Mathematics-based occupations are projected to grow at approximately twice the rate of the total labor force.
- The total number of workers with college educations needed between 1985 and 2000, from retirements and new jobs, is more than 12 million. If current trends continue, that number is approximately the total number of new graduates between 1985 and 2000 and does not allow for mismatches between training and job requirements.

- The National Science Foundation projects a shortage of approximately one-half million scientists and engineers by the year 2000.

The following summaries give information concerning the demographic changes:

- Native white men, 47 percent of the 1985 labor force, will constitute only 15 percent of the new workers between 1985 and the year 2000.
- White women receive 40 percent of the bachelor's degrees in mathematics but only 17 percent of the doctorates.
- Blacks and Hispanics, relatively few of whom now study mathematics, will increase from 22 percent of the college age population in 1985 to 27 percent in 2000 and 30 percent in 2010, while the total population in this age group will decline by 18 percent between 1985 and 2000.
- In general, attrition from the mathematics and statistics "pipeline," although not uniform, is approximately 50 percent each year from ninth grade through the doctoral degree.

Another issue of concern is a projected shortage of mathematical sciences faculty. There is concern about Ph.D. production and our ability to replace retiring faculty. Also critical is the fact that faculty size has not grown in proportion with enrollments. The following data summaries and projections attest the validity of these issues:

- During the period from 1970 to 1985, when enrollments in mathematical sciences courses grew by 60 percent, the number of full-time faculty increased by only 18 percent. The faculty at research universities decreased by 14 percent. To compensate, the part-time faculty more than tripled during this same period.
- Current degree production is 15,000 bachelor's, 3,000 master's, and 800 doctorates each year—approximately the levels of the mid 1960s.
- One-fourth of the bachelor's, one-third of the master's, and three-fourths of the doctoral degree holders in mathematical sciences work in educational institutions.
- The percentage of bachelor's degree recipients who received doctorates seven years later is 4 percent for mathematics as opposed to 15 percent for physical sciences.
- By 1995, the current level of U.S. doctoral production will not be sufficient to replace the expected number of retirements at four-year colleges and universities.

In universities, the number of mathematical sciences faculty has decreased from approximately 7,000 to approximately 6,000. At four-year colleges, there has been a slight increase in faculty size, while at two-year schools it has been fairly constant. This shortfall has been compensated for with part-time faculty and graduate students.

Finally, faculty salaries in general have decreased over the last 15 or 20 years. However, in some cases, the salaries of statisticians have increased.

I have listed some of the problems, issues, and concerns uncovered in our work on MS 2000. The reports will contain a very detailed presentation of the data, the resultant conclusions, and strategies for addressing the situation.

7 RENEWING U.S. MATHEMATICS

A synopsis of progress since the 1984 David report is provided. Preliminary plans for dissemination of the 1990 update of the David report are described. Discussion focuses on the role mathematical sciences department chairs can play in the dissemination effort and the community support they will need to use the report effectively.

RENEWING U.S. MATHEMATICS

Lawrence H. Cox, National Research Council

RENEWING U.S. MATHEMATICS

Lawrence H. Cox
National Research Council

When this program was planned, we anticipated being able to give a great deal of information about the David II report. However, that is impossible because the report remains under development. According to policies of the National Research Council, reports and their recommendations cannot be discussed in any detail until they have withstood a rather stringent review process. Thus, the discussion today will be in the abstract—not about the report, but about how the community can make best use of a report on the mathematical sciences research enterprise. However, it is an important first discussion that may lead into similar discussions that are planned by the American Mathematical Society and probably by others. We expect the report to be available to you by April 1990.

I will tell you what the Board on Mathematical Sciences has been asked to do and what the report committee took as its charge. Then I would like to discuss possible uses of the report and its dissemination within the university context.

The first issue before the report committee is research support. The 1984 David report stated that funding for mathematical sciences was out of balance with the other sciences. It found that there were some 1,600 to 1,800 supported principal investigators out of 2,600 highly active researchers in the mathematical sciences. Those were people who produced at least one paper per year over a three-year period of reference. In gathering data in preparation for the work of the report committee, we found that there are now some 1,900 supported principal investigators. So there has been some improvement, but this is much less than 2,600, which was the goal set by the David report.

In 1984, postdoctoral and graduate student support was low. In 1989, we see a great deal of improvement across the spectrum of all the agencies, especially the National Science Foundation. However, a few comparisons are in order. Graduate students supported in the mathematical sciences are 18 percent of all graduate mathematical sciences students. Close to 50 percent of graduate students in programs leading to the doctorate in the physical sciences are supported. Additionally, in chemistry and physics, there are approximately 1.2 postdoctorals for each Ph.D. produced; in the mathematical sciences, 0.16, roughly a factor of 8 differential.

The David report asked for 130 percent real growth in mathematical sciences research funding over a five-year period. The five years have passed and there has been some progress. There has been real growth of 41 percent.

The second issue before the community is that of human resources. Due in part to funding problems, but also attributable to the way we present the field to new entrants and the way we develop new talent, many believe that careers in the mathematical sciences are viewed as less appealing. Especially important here are the issues of domestic Ph.D. production, female and minority entrants into the mathematical sciences, and the role of the research establishment in national mathematics education reform.

The third area of focus in the charge to the committee was the research, the output, of our community. We all know that high quality and U.S. leadership continue to prevail. However, these are threatened by the factors above.

New opportunities for research are being rapidly created. This is especially due to the use of and interface with the computer. There is also strong evidence that researchers individually, and the research community at large, are looking outward to other fields, both in their research and in their interactions. This is easily seen in the newsletters and meeting programs of professional societies, and from the agendas of their committees. It was documented in the 1987 BMS report, *Mathematical Sciences: Some Research Trends.*

These are national issues. I believe that a national response to the first issue—research funding—is dependent upon community and university response to the second set of issues—career paths, the development of scientific manpower, and the directions and impact of our research output.

I would like to begin the discussion of how the report under development might be used by a mathematical sciences department chair. I jotted down some sample areas. To whom should the department chair present the report? How should the report be presented? Should it be presented informationally or coupled with a request for resources? Should it be presented in conjunction with an existing or in-process departmental plan to address national issues and, in particular, university issues of interest and concern? What additional support would a department chair need to effectively use and present this report?

The first report made recommendations to the federal community, to the mathematical sciences community, and to the university community. I gave you the quantitative information about the federal response. That is basically a dollar issue directed toward graduate students and postdoctorals. The mathematical sciences community has responded in a variety of ways in the last five years; education issues have been examined and there has been expansion into cross-disciplinary research. It is safe to say that the response within the university community has been nearly zero. My view is that community action has to precede university action; possibly the community needed a period of time to consider and work with the report before the information could get into the university hierarchy and the resultant actions taken. This is the motivation of the question of a national plan and group thinking about this problem.

PARTICIPANT: A national effort is crucial. *The Chronicle of Higher Education* and other media that come to the attention of higher administrators must be exploited. There is also the Association of American Universities, the presidents' organization. These are all media one must utilize if one wishes to apprise higher administrators of the fact that the future of the United States as a world power depends on their support of mathematics. That may be an expansion of reality, but that is what we really want to say to them.

I believe every effort must be made to bring this issue to the public. As a product of the post-Sputnik era, I recall what happened when that was done, when the need was manifest throughout the country and pressure was put on the federal government to fund fellowships for graduate students and research opportunities for mathematicians and other scientists.

PARTICIPANT: Let me give you the view from the standpoint of statisticians to whom I have talked. Their general view is that the David report did not help statistics. There was the feeling that a shell game was being played with the government. Look at the shape our country is in: quality control is lousy, reliability is lousy, and we do not know how to manage epidemics. Therefore, we must spend more money in ring theory and algebraic topology.

PARTICIPANT: Our dean is not convinced he should support ring theory and algebraic topology. He is convinced he should support chemistry and physics, because there is no money for mathematics. I gave him a copy of the David report. It has not been adopted.

PARTICIPANT: It might be useful for you to seek and distribute a few successful case studies of how the David report and subsequent supporting information have been used to advantage.

DR. T. LANCE (SUNY, Albany): A two-pronged attack works very well. Around the time the David report was released, we were getting no support and no promises of support for a decade. We had been aggressively recruiting American students and were beginning to succeed. The administration has turned around and is supporting mathematics to the exclusion of support of chemistry and physics. The report did help.

PARTICIPANT: If we use the report individually, we may have some isolated successes. However, if we can get it on the agenda of administrators' organizations, so that they are discussing these ideas among themselves, we will have a greater chance of having a broad impact from this report.

DR. COX: One of the comments expressed to me about this meeting was that new chairs viewed this meeting in a sense as a tutorial on how to be a chair, which is not its intent. Would information on how to use the report be of help to new chairs?

PARTICIPANT: Yes.

8 STATISTICS AND OPERATIONS RESEARCH IN THE 1990s

The discussion that follows concerns trends and challenges that departments of statistics and operations research may face in the coming decade.

STATISTICS AND OPERATIONS RESEARCH OVERVIEW

Jayaram Sethuraman
Florida State University

At the end of each decade, we consider the state of our profession. By our profession, I mean the teaching of statistics, statistics curricula, and statistics departments. The old controversy on too much theory or too many applications in our courses is essentially over. We now recognize that we need both the theory and the applications.

At the present time, I see three main challenges in our curricula that need to addressed. The challenges come from industry, computers, and the need for cross-disciplinary work. Industry has been demanding that we produce more statisticians to help improve the quality of manufactured products and meet the challenge they are facing from other nations. This has led us to revise our curricula and introduce new types of courses. These courses include the design of experiments and other topics such as optimal stochastic control.

The second challenge has come from the availability of powerful and inexpensive computers to do our calculations. Resampling techniques, bootstrapping, and many other methods have become commonplace because of the availability of computers. Also, computers spawn new theory, and the theory leads to more computation.

The third challenge is coming from sister departments in our universities. There has been a flight of service courses from statistics departments to other academic departments. Additionally, some of the new developments in research in statistics are coming from these departments. Statistics departments should cooperate in a team effort with these departments and develop appropriate curricula. There is a need for interdisciplinary programs in statistics.

IMPROVING THE COMPETITIVE POSITION OF U.S. INDUSTRY: CHALLENGES FOR STATISTICS AND OPERATIONS RESEARCH

Jeffrey H. Hooper
AT&T Bell Laboratories

I speak to you today in three different roles: first as a worker in a U.S. industry that is struggling to compete in the world market; second, as a quality practitioner trying to improve our ability to compete; and finally, as one who believes that our universities are a central part of the long-term solution to the problem of competition that is facing U.S. industry.

My message is short and simple. The problems facing U.S. industry are very serious and threaten our ability to compete. We have been trying to address these problems for approximately a decade. Some progress has been made, but our progress is much too slow. We need more help and support from our universities if we are to improve more rapidly.

Many factors affect the ability of U.S. industry to compete. However, the essential problem is simply that there are many world-class competitors who bring products and services to market more quickly, at lower cost, and with higher performance and reliability. Industries facing severe competitive pressure include consumer electronics, semiconductors, automobiles, and telecommunications equipment.

As serious as these problems are today, they will be even more difficult in the future. One reason is that there will be three powerful economic centers in the 1990s: the Pacific Rim, the European Economic Community, and North America. The United States will no longer be in a dominant position. This will have very serious impact, not just on our companies but on our universities as well. The reduced market share and profit margins of many U.S. industries will result in a loss of jobs and the erosion of our standard of living.

Just as there are many causes of our problems, there are many parts to our response. However, the core of the response adopted by many U.S. companies is total quality management. This involves a complete change in how and what we manage in our businesses. As you can imagine, this is a very difficult thing to do.

But the idea is incredibly simple. Its essence is that we spend too much time trying to manage results and symptoms when we should be managing what we do and how we do it. That is, we should focus on the customer and understand his needs and expectations, align our value-adding processes to meet these customer needs and expectations, and continuously improve the effectiveness and efficiency of all the processes by which we add value for the customer. One result will be increased customer satisfaction. Hence, revenue and market share will increase. Another will be decreased cost through increased efficiency. Together, these will have enormous impact on profit.

Everyone in the company must be involved. Issues such as teamwork and enabling and empowering individuals must be addressed. The objective is to get everyone to improve the efficiency and effectiveness of their work processes. To accomplish this, data must be collected and analyzed on all work processes to determine how to improve them. Everyone must understand how to do this. This means understanding the simple concepts of planning experiments, collecting data, and analyzing data to provide fact-based rather than opinion-based management. It means understanding the concepts of variability because all operations require the separation of signals from noise. And it means understanding process flow charting, process analysis, and process control and capability.

To date, entry level workers have not had the kind of knowledge and skills required. This has resulted in massive training and education programs in U.S. industries. For example, at AT&T we are faced with training 280,000 people. That is far beyond the scope of any previous training and education program. Now you, in a sense, are our supplier. We need to form a partnership to reduce the scrap and rework in the existing education process. We do not want to continue such heavy involvement in the education business. There are many things that must be done to form this partnership. One of the first is to understand where the problems are, what the problems are, and the environment in which these problems have to solved. Universities need to understand industrial needs. There is no better way to gain this understanding than through consulting relationships involving both professors and students.

With respect to general education and training, everyone needs to be quantitatively literate. The degree of quantitative literacy of many people coming from fields outside of mathematics and engineering is extremely low. Many people go into symbol shock if they see "x-bar." There is a great deal of work to do here. Industry views many of the people in this room as having the responsibility to help solve this problem.

Statistics and operations research departments should reexamine the role of service courses taught to other departments. We need more cross-disciplinary teaching. Those not in your field need to understand how to use your methods to solve their problems. They do not want to become specialists in your field, but they need to understand what you have to offer and how it can help them. Ideally, your methods should be integrated into their courses.

Universities can also help with the rework process for people who are in the workplace today. Short courses for industry are very important. A growing number of universities are making real contributions in this way. This is a lucrative activity. It builds trust and communication and helps the university faculty understand industrial needs.

The last topic I wish to address is research. There are many research opportunities with industry. I am much less pessimistic about this than Dr. Lieberman. But you will not be successful at developing these opportunities if you view industry as suppliers of money that you can spend as you alone see fit. Industry is looking for a partnership where universities take the time to understand and solve long-term industrial problems. For example, the Semiconductor Research Corporation has been a successful partnership between industry and academe. Here the semiconductor industry is channeling over $20 million a year into focused university research projects. This has resulted in useful long-term research programs, increased faculty understanding of industrial problems, and students very well prepared for industrial positions. The support for this work is growing.

Many similar opportunities exist in fields such as statistics and operations research. Industry is convinced that quality and productivity are critical to their success. It remains for you to convince industry that your work can improve quality and productivity. Take the view that we are a customer or a potential customer. Take the time to understand our problems. If you can show how your work helps solve our important problems, it will generate enthusiasm and support.

Other opportunities can be found in industry's relentless drive for new technologies. These technologies open up new areas for your research, but without partnerships between industries and universities, you will not know the areas of future importance. For example, intelligent networks are likely to be an immense future business. These networks will have greatly improved capabilities for managing and moving information, but research needs to be done in many areas of dynamic reconfiguration of these networks. Areas such as fault-tolerant design and network reliability, nonhierarchical routing algorithms, and large distributed databases must be addressed. The quality of the data in these databases, data on which we run our businesses, is three orders of magnitude worse than the quality of our electronic components. Most of our databases average approximately five percent defective, whereas our components are running about 50 defective parts per million. I know of only a handful of people who are working on this problem. Lightwave technologies are opening new areas.

Additionally, there are many opportunities in computer-aided engineering and computer-aided design.

In conclusion, a more effective partnership between industry and academe is essential if we are to improve the competitive position of U.S. industry. At the same time this partnership will address the growing university problem of obtaining long-term financial support.

STATISTICS AND OPERATIONS RESEARCH IN THE 1990s

Gerald J. Lieberman
Stanford University

The mission of any department in a university is teaching and research. Departments of statistics and operations research in the 1990s will be judged by these criteria. The 1990s will pose severe hardships on these departments because of tight budgetary constraints, on both the academic side and the research side.

Both public and private universities are faced with tight budgets. State-supported schools are suffering because of limited available funds earmarked for education. The needs of states for funding social programs and the reluctance of legislatures to increase taxes result in belt tightening for education. For private universities, the cost of academic programs continues to exceed the cost of tuition, and we are near the limits on this important component. Therefore, senior academic administrators, such as deans and provosts, will be scrutinizing what I call nonmainstream departments such as operations research and statistics. One does not hear of a university without a mathematics department, but we all know of universities without statistics or operations research departments. Therefore, what can such departments do to enhance their positions?

I have a few suggestions. There must be a genuine interest in "service course" teaching where we spread the gospel to the "uninformed." This interest must be matched by teaching performance in these classes. There are too many departments in every university that teach their own courses in probability, statistics, and operations research. We cannot expect the dean to mandate that these courses not be taught in peripheral departments. Indeed, in my experience, they often do a better job than mainstream departments. It is a matter of competition. If we do the better teaching job, these departments of psychology, sociology, industrial engineering, and electrical engineering, etc., will send their students to our elementary courses. At the same time that we teach service courses, we must nurture our own majors, and provide them with the education we both want. At the bachelor's and master's levels, we must train our students to go out to the real world and apply the techniques of statistics and operations research to problems faced by government and industry. The educational program of the students must reflect this mission. Finally, one of the most important problems of the 1990s is the issue of affirmative action. We need more women and minorities on our faculties and in our student bodies. To be successful in the former, we must increase the pipeline of the latter.

The research issues faced by departments in the 1990s are intricately linked with the doctoral program. Many of us have been fortunate enough to have research support for our graduate students. As the federal budget tightens, and it will become even tighter than it is today, research support will be threatened. Not only does this affect the faculty member directly, but it will place heavy pressure on graduate student support as well. As this source of funding is diminished, the number of doctoral students will be reduced. Not only will this have an adverse effect on the research program of the faculty member, but it will have a negative impact on the graduate program in the department. This is one of the most difficult problems to resolve because of our long history of federal support. Perhaps this support can be replaced by state and industrial support, but I am somewhat pessimistic.

I have said little about the profession in the 1990s. Here, I am optimistic. In government and industry, there seems to be less need to continually justify the existence of trained statisticians and operations researchers. Indeed they are, and will continue to be, in demand. This is the challenge for universities.

ISSUES IN STATISTICS AND OPERATIONS RESEARCH

Jerome Sacks
University of Illinois

A number of issues have been described by the previous speakers, not only in this session, but also in earlier sessions. They have focused on education. However, they have not covered the entire panoply of educational issues.

There is an industrial issue of making sure people in industry are trained properly. The entire defense industry is involved in the issue of training its workers in statistics.

We are also concerned about the relevance of graduate education, relevance not only for doing research and teaching, but also for entering industry and government. The issue of service courses for other departments and the need for quantitative literacy throughout the university must be addressed. Additionally, the emergence of statistics in pre-college will create a greater demand for statistics at the undergraduate level.

It would probably take twice the resources currently available to address the educational issues just mentioned. That list does not connect with research. In research we have a shrinking federal research budget for statistics in particular, and for mathematics in general. This has happened in part because of policy decisions, in part because of the federal budget, and in part because of the failure of the mathematics community to adapt to changing realities, needs, and opportunities.

One of the realities is motion and outreach. I don't like the word "outreach." We must really "connect" to other sciences, other departments, and industry. To connect in this arena is not a question of opportunity, it is a question of necessity.

I do not wish to repeat what Dr. Hooper described as necessity. Just let me underline the fact about the competitiveness of American industry. That issue alone is enough to drive all of our work.

Where does this bring the statistics community? I think it relates to the differences between the little science attitude we have traditionally had and the big science attitude that is being pressed upon us so that we can address existing and emerging problems. We are not conditioned to do big science. However, one cannot do little science and expect to have an impact on nuclear fusion, on the greenhouse effect, or on anything requiring collaborative effort with a variety of scientists and a variety of tools.

A tremendous agenda faces us in the 1990s, and the human resources are not available. Part of the problem is lethargy. The carrot and stick approach, mentioned yesterday by Dr. Reed, may sound drastic and unpleasant, but we may need to employ it to drive the mathematical sciences into doing something meaningful.

There is a fundamental dilemma. We do not have enough resources to deal with the educational needs. To divert resources into developing the human resources means neglecting the absolute necessities of research. I do not know how that will evolve.

We do have a strategy available to us to push ahead, a strategy that is perhaps foreshadowed by the NSF's regional geometry institutes. We must merge the research interests with the educational and public relations interests of our fields in a way that will reinforce or create a public image that ours is not a dull, dry, and irrelevant subject, but something that is dynamic and essential to life on this planet as we know it. If we should fail, well, at least we can go out with a bang and not a whimper.

QUESTION-AND-ANSWER SESSION

QUESTION: There seems to have been at least one prospective model for industry/university cooperation in biotechnology development in terms of jointly funded institutes and industry/university personnel exchange. Do you view this as a valid model for what you would like to see in statistics?

DR. HOOPER: I have seen two models. I am somewhat familiar with the one you mention. However, I am more familiar with two others. Semiconductor Research Corporation is a consortium of about 40 U.S. semiconductor companies, each of which contributes, according to a formula, to a fairly sizable fund—in the $20 million range. The money is apportioned to the universities to do research in problem areas important to that field. This consortium has been extremely effective. It not only produces students who really understand current industrial problems, but it focuses a lot of good, solid research on some of those problem needs.

A much smaller one, in more fundamental research, is concerned with superconductivity. AT&T and IBM are entering a partnership with MIT for a major research thrust in the area of superconductivity.

I do not think there is any one model. There are many models that could work. It depends on the stage of the technology and how fundamental the research is. There are many opportunities to use ingenuity in these areas because the partnerships are sorely needed.

DR. SACKS: There is an emerging development in some universities: the centers sponsored by the NSF and the DoD. Some of them have industrial components and research activity that combine a number of efforts.

Large institutes are also developing. We have one at the University of Illinois, for example, the Beckman Institute. There is a similar center at Cal Tech. Both of them have industrial components. One sees a variety of strategies to attempt this coalition of effort to advance in appropriate directions. Unfortunately, the mathematical sciences are not as well represented in these areas as they might be. That is due in part, perhaps, to the pathology in our sciences and in part to the shortage of manpower.

PARTICIPANT: There is a problem with the suggestion about teaching in other areas to teach our methods. One of the problems with operations research is that its methods are being taken over and taught by other areas. Electrical engineers are using and teaching queuing theory. Business departments are teaching linear programming. Also, statistics is being taught in psychology and sociology departments.

We face competition in working with industry from people in other disciplines who are also working with industry. Maybe they don't know our methods as well as we do, but this is a potential problem. It is going to impinge upon our support, our majors, and our research.

DR. HOOPER: It gets to the heart of whether you view it as bad that they think your methods are important enough to teach themselves or whether you view them as competitors. If you view the other departments as value-added resellers for what you have and you are providing them with additional insights into how to teach your methods, apply your methods, or even develop new methods, then you will have more impact and not have to do all of the teaching yourself. I think you may need to take a more business-type view of a different kind of business relationship with them instead of viewing them as competitors. You could be suppliers to them in a very constructive way.

PARTICIPANT: I was struck by Dr. Lieberman's remarks on the disparity between the agenda he has laid out and our resources, in terms of manpower, to accomplish that agenda. That leads me to wonder if perhaps we need a little setting of priorities as a profession. For example, there is a massive effort now to restructure the teaching of calculus. Given the concern about basic statistics, perhaps we need to restructure basic statistics courses. Maybe we need our own version of the David report for purposes of clarity on our part about what our priorities are as much as for purposes of promoting a greater sense of community within the statistical sciences. Would you like to comment on that?

DR. SACKS: You are absolutely right. The field needs that sort of thing.

9 FOSTERING UNDERGRADUATE PROGRAMS IN STATISTICS

How to develop, nurture, and sustain an undergraduate program in statistics is discussed by a panel of statistics administrators.

Jayaram Sethuraman (Organizer), Florida State University

STATISTICS AS AN INDEPENDENT UNIT
Dean L. Isaacson, Iowa State University

THE CARE AND FEEDING OF UNDERGRADUATE STATISTICS PROGRAMS
Walter R. Pirie, Virginia Polytechnic Institute and State University

THE UNDERGRADUATE STATISTICS MAJOR
James R. Thompson, Rice University

STATISTICS AS AN INDEPENDENT UNIT

Dean L. Isaacson
Iowa State University

It may seem somewhat paradoxical that statistics asks to be an independent unit and at the same time claims to be a part of most scientific research. How does statistics establish an identity when the subject is being taught in many departments across most campuses? The importance of data collection and analysis is spread throughout the college or university so that students do not view statistics as a separate discipline. This paradox represents both a problem and an opportunity.

Statistical methods courses are often taught in departments outside of statistics by professors without a degree in statistics. Hence, there is no natural "home" for applied statisticians. The theoretical statisticians are often absorbed into mathematics departments and then tend to become mathematicians in order to get promotion and tenure. This lack of a natural home where statisticians can be nurtured has hurt the visibility of the discipline and in turn has made it difficult to establish an undergraduate program. We must pull statisticians together into a single unit so that students recognize it as a viable major.

The first step is to separate statistics from mathematics. Statisticians cannot move freely between theory and applications if tenure decisions will be made by theoretical mathematicians. Within a mathematics department there will be no incentive to do statistical consulting and collaborative research. So a significant portion of statistics will wither and die. There are also problems associated with having mathematicians teach statistics courses. The theorem-proof approach is often used, and hence students cannot see the difference between mathematics and statistics.

In most colleges and universities, the number of statisticians in the department of mathematics is not great enough for the formation of a separate department. They also usually lack the breadth to satisfactorily cover the statistical methods being taught and used on their campuses. Hence, the next step should be the centralization of applied statistics. This may be a sensitive issue on many campuses, but with help from central administrations, it can be done. On most campuses there are courses in business statistics, engineering statistics, educational statistics, psychometrics, econometrics, etc. These courses should have primary listing in the department of statistics so that the material is recognized as statistics, and students who enjoy the material might consider a major in statistics, or a double major. It is not feasible to hire new faculty members to teach these courses, and so the existing faculty should be given fractional appointments in statistics. In this way, all of the "applied statisticians" would interact on a regular basis and thereby keep current in statistics. The applied courses would still be taught by individuals with expertise in the field of application. Through the above process, statistics could be centralized on campus. This would give it strength and size and hence a competitive position as a possible major.

If students choose statistics as a major, there must be some flexibility in the curriculum. These students will have different career goals, and so they must have a variety of courses from which to choose. This is impossible to do if the courses are designed for statistics majors only. The theory courses should be designed and taught in such a way that undergraduate students in mathematics and engineering will also take the courses. Similarly, the applied courses should give adequate graduate credit to majors in the sciences. Hence, courses in design of experiments, survey sampling, quality control, regression, etc., will be filled primarily with graduate students from outside statistics and also will be available to the undergraduate statistics majors. By listing all of these courses through statistics, control is maintained so that the courses remain appropriate for an undergraduate major.

A successful undergraduate program must also be separate from the graduate program. At many universities the graduate statistics program is strong and the undergraduate program suffers by comparison. In such cases, there must be an undergraduate coordinator who acts as the administrator for the undergraduate program. If possible, a separate "main office" with secretary should be used for undergraduate matters so that the undergraduate students do not get pushed aside when seeking advice. There also should be a core of undergraduate advisors who take the program seriously and are rewarded for doing that part of their job well. This subunit, no matter how small, gives the undergraduates a sense of unity and a home within the larger program.

The resources needed to run an undergraduate program will vary. In most cases the resources are already there and simply need to be pulled together and identified as a program. Through joint appointments, selection of an undergraduate coordinator, selection of the undergraduate secretary, and centralization of statistics courses, a viable department can be formed. The main resources it needs are encouragement and respect.

THE CARE AND FEEDING OF UNDERGRADUATE STATISTICS PROGRAMS

Walter R. Pirie
Virginia Polytechnic Institute and State University

I wish to talk today about how to make undergraduate programs work, both for the department and for the students. Both aspects are equally important for the success of the program. My colleagues this afternoon have provided some important insights into the administrative aspects, both nationally and within the institution. One has also discussed some unique problems for small departments. I wish to focus mostly on undergraduate programs within statistics departments in large universities that have heretofore existed primarily for their graduate programs. That is my primary interest and my background.

Program Content

How should a program be designed? I think the operative phrase is "by intent" and not by default. By that I mean the program designer(s), after some careful thought, should come to an intellectual conclusion about the desired nature of the program. Necessary actions should then be taken to allow that program to be implemented. If local conditions demand major compromises and a considerably weaker program, the project should be abandoned. This is particularly true of undergraduate statistics programs. Despite the continuing health of the discipline, demand will never warrant a statistics major at every college and university in the country as for mathematics or physics. It is in everyone's best interest that only those who can support well-designed programs should do so.

Although diversity and flexibility of program content are desirable, I think most would agree on a few basics. A program should be designed around a core of required courses. That core would likely be similar in most programs, including the most commonly used statistical methods, a solid introduction to probability and statistical inference, mathematics that includes calculus and matrix algebra, and some use of computers.

Beyond the core there is room for considerable flexibility, but a program should demand considerably more statistics than just the core, whichever direction it chooses. If not, it is more appropriate to call it a concentration rather than a major. The guidelines published in *AMSTAT News*, June 1986, cover this in more detail.

Who Should Teach the Courses?

Physics is not considered to be a branch of mathematics just because it uses a lot of mathematics, nor is computer science. True, advanced theoretical topics in statistics are very mathematical, but statistics is not a branch of mathematics. It is a science in its own right and cannot be adequately taught by most mathematicians (or psychologists, or Ed.D.s, etc.), at the very least, not to future statisticians.

To offer an appropriately broad degree program in statistics requires a core of professionally educated statisticians. I don't claim to have a magic number, but I cannot imagine it with less than three or four professionally qualified statisticians. Can anyone envision a mathematics degree program with fewer faculty? As David Moore has said, "it is unprofessional for mathematicians who lack training and experience in working with data to teach statistics."

Enrollments

How does an undergraduate statistics program attract the students necessary to warrant a strong program with a sufficient variety of courses? The answer comes in several pieces. In the introductory-level courses, it is usually satisfactory to combine majors and general service teaching; so enrollment is often not a problem. In upper-division courses, that is often not the solution. Courses need to be designed more specifically for the statistician. In a major research institution, such courses will still attract some students from other data-oriented disciplines, and offering a minor in statistics will also be effective. Many smaller institutions will have to rely on majors only for these courses.

The question becomes one of how to attract and hold not just numbers of students but also highly qualified ones. The factor that makes this difficult is that most high school seniors are not even aware of statistics as a separate discipline. One of my major points is that the traditional practice of relying on transfers from other disciplines is not satisfactory. Often the numbers will not be adequate, and few if any will be the high-quality students we need to attract. The only reliable way to consistently maintain both the quantity and quality of students is high school recruitment.

The experience at my home institution over the past decade is that in years when we sent a mailing to high schools throughout the state, our freshman classes varied from 15 to 20. When we have not used a mailing, the numbers have been two to eight. We have found this to be a very effective recruitment mechanism that utilizes relatively modest resources in terms of cost and faculty time. The alternative of faculty visits to high schools is resource-intensive and reaches far fewer students. This year we have added a direct mailing to students whose names were selected from the PSAT list, which is available to admissions offices, and so far, that seems to be effective also.

Then, of course, there is the issue of keeping the good students and building a reputation within the institution. Professor Isaacson has already discussed the importance of that. Students must feel that the department values the undergraduate program. That issue still requires a change in attitude for many statistics faculty members.

What we have discussed today is not revolutionary. With the exception of a greater need for recruiting, we are simply emphasizing what happens in most good programs in any discipline. It is just that in statistics we have not paid much attention to undergraduate programs in the past.

THE UNDERGRADUATE STATISTICS MAJOR

James R. Thompson
Rice University

Thinking back on my past doctoral students, I recall that two of them had undergraduate majors in English. One was a Chaucer specialist, the other a Beowulf enthusiast. Other doctoral students had done prior work in sociology, physics, electrical engineering, and medicine. Such backgrounds might seem bizarre for aspirants to doctoral work in mathematics. In statistics, they are not unusual. Each had as his major motivation for doing doctoral work in statistics not the techniques of mathematics but rather the uses to which statistics might be put in attacking the problems of science.

It appears to me most appropriate that undergraduate statistics majors should have majors in other university departments as well. At Rice, all of our undergraduate statistics majors have another major in addition to statistics. We have some majors who quite frankly pick one major, such as English, independent of any prospects of a profession in the area, and another in statistics because they find it interesting and it offers promises of future employment. I do not find this strange or insulting to statistics. It seems to me, on the contrary, an intelligent approach to one's undergraduate curriculum. Of these students, many will seek employment in statistics without further academic training beyond the bachelor's degree.

A statistician who has expertise only in the mathematical techniques of his discipline stands outside the historical mainstream of the field. Statistics began in earnest during the Victorian Enlightenment. Galton and Pearson were not very good mathematicians. They were, however, very good scientists and individuals whose interests stretched from psychology and ethics to astronomy and agriculture. It is this fundamental curiosity which, more than any other factor, defines a statistician.

If I must write down a list of fundamental statistics courses for a statistics major, I am in a much greater quandary than if I were given a similar task for a mathematics major. Every mathematics major should have an essential core of courses in algebra, complex analysis, and real analysis. This may well extend to a list of at least ten courses beyond calculus and differential equations.

For a statistics major, I will grant the necessity of a Hogg and Craig type course. Beyond this, however, a wealth of paths becomes feasible. One student might, for example, spend a great deal of time in probability theory and stochastic processes, together with the pure mathematics courses required to handle them. Another student might elect a concentration in psychometrics. Still another might elect to press forward with concentrations in a classical statistics curriculum with courses in sampling, experimental design, Bayesian analysis, and linear models. Which is the correct curriculum? What is the irreducible core? I cannot answer these questions, and I am troubled by the excessive confidence of those who think they can.

This may be unfortunate, for statistics is a profession, and there is a keen need for a plan to accredit undergraduate statistics programs. Such plans are currently under consideration by the American Statistical Association and the Southern Regional Committee on Statistics. Statisticians are beginning to notice that their present position as members of a subcategory of applied mathematics is serving their profession ill. They find that, in problems where their expertise is acutely needed, they may have little if any voice. Examples abound. The quality control considerations of the Challenger disaster were dealt with cursorily by a physicist. In the matter of AIDS, it was a matter of embarrassment to all when it was discovered how lacking were the Centers for Disease Control in statistical expertise. It is not simply a question of fighting over turf that is at stake here.

Rather, we have to deal with the reality that there are statistical questions of considerable importance that receive the shortest of shrifts because of the institutionalized impotence of the profession of statistics. So long as statistics is perceived as a proper subset of mathematics, this impotence is likely to continue.

This does not mean that I side with those who would make the union card in statistics an ability to run an SAS System program. Mathematics will always continue to afford valuable transferrals of methodology to statistics, and it ought not be despised by any statistician. H.O. Hartley once observed that there is a tendency of some statisticians to regard as irrelevant any branch of mathematics that they could not readily understand.

What then should be the criterion for accrediting undergraduate programs in statistics? In my view, it should be a commitment of such programs to prepare the student for doing original modeling and inferential work in science generally. The gate must be sufficiently broad that the stochastic process enthusiast and the quantitative agronomist can both pass through. It must be sufficiently narrow that the student with only a casual interest in the discipline cannot pass.

The judgment must of necessity be based on the interests and orientations of the faculty who manage the undergraduate program in statistics. Do they carry out original statistical research? Do they carry out statistical consultation for industry and government? Do they show evidence of interdisciplinary research with faculty from other departments? What are the stated goals of the managers of the program? How realistic are these goals in the light of the curriculum and the student population? The questions may sound as though a great deal of subjectivity must be involved in their answers. I doubt that the subjectivity problem will be as serious as might be supposed.

Statistics programs at smaller universities are presented with special challenges. First of all, such programs must rely substantially on joint faculty appointments with other scientific departments, to provide diversity and stimulation for their students. At Rice we have only four full-time statistics faculty members. (Naturally, we are doing our best to increase the number of full-time faculty.) Yet we manage to run an undergraduate program and a doctoral program. (Interestingly, of our nine doctoral students, all are U.S. citizens except for one Mexican national.) We run a weekly seminar, and both graduate and undergraduate majors are encouraged to attend. Without our joint faculty, our task would approach nonfeasibility. Joint faculty are not interested in teaching solely low-level service courses; at Rice they teach upper-level undergraduate and graduate courses as well. A good deal of care and stroking is required to ensure the cooperation of the joint faculty. As a side observation, I have noted that it is easier to obtain the participation of joint faculty within the structure of a department of statistics than it was when we were a proper subset of a department of applied mathematics. At Rice a number of upper-level undergraduate statistics majors take some graduate statistics courses. Given a choice, most statisticians would like to see a group of eight or more full-time statistics faculty in a department of statistics. With some care, however, the job can be done with fewer.

If statistics is to achieve Pearson's ideal role as the grammar of sciences, then academic statisticians must turn their attention more to the scientific method itself and less to mathematical technique. The undergraduate curriculum should reflect this realization.

QUESTION-AND-ANSWER SESSION

QUESTION: How do you choose the target for your mass mailing?

DR. PIRIE: What we do is quite simple. We mail a copy to every high school in the state. Also, the Department of Education publishes a list of high schools that excel. We target those in nearby states.

This year, we added to that a mailing to high school juniors based on PSAT scores. The admissions department at the university or college can get a copy of the results of the PSATs. We sent letters to those who did well and expressed interest in mathematics. The budget for all of this is well under $1,000 per year.

PARTICIPANT: I would like to supplement what you have said and give a slightly different view. I am from a small university. We have a mathematics and statistics department with four Ph.D. statisticians. We do not have the size or the number of majors to have a separate statistics department. We have actually been able to do what Dr. Isaacson recommended. For example, we recognize consulting as professional work. One of my goals is to attract enough majors so that statistics can become a separate department. The problem that a lot of us face is trying to get an identity for statistics.

Accreditation may work against the profession. The fact is that we will not be accredited. We do not have enough students or enough statisticians, and we probably cannot offer the courses. The university has limits on what can be offered as a major.

If your accrediting plans follow those of every other accrediting agency, they will be self-serving. You may end up cutting out departments, such as ours, that want to produce bachelor's degree students in statistics and eventually grow into the position of which you speak.

DR. THOMPSON: You are right; it is self-serving. Many years ago, I read an argument by Milton Friedman that indicated that accreditation of lawyers, doctors, engineers, and so forth was in the interest of the professions that were accredited, but it was not necessarily in the interest of society at large. He convinced me with that argument. However, I do not see any way statistics is likely to break out of its non-identity until it considers such options as accreditation and splitting off from mathematics. None of the funding agencies from the federal government, to my knowledge, has a separate directorate for statistics. We are always included as part of mathematics. If you think that serves us well, I must respectfully disagree.

QUESTION: I can easily imagine accrediting a three- or four-person mathematics department. Thus, I was expecting to hear you say that there is nothing wrong with four people in statistics if that is the right number with respect to the number of students and the nature of the university. Can you imagine accrediting a three- to four-person statistics department?

DR. THOMPSON: I can do what I do with four people. I could not do it with three. There is a minimum size staff. I can see accrediting small statistics departments. However, it is very uncomfortable because there would be no slack in terms of personnel. Every day would be crisis management. Eight people would be a nice size, I think, for a statistics department.

APPENDICES

A: 1989 Colloquium Presenters

B: Commission on Physical Sciences, Mathematics, and Resources

APPENDIX A: 1989 COLLOQUIUM PRESENTERS

Lawrence H. Cox is director of the Board on Mathematical Sciences. Previously he was the senior mathematical statistician and assistant chief, Statistical Research Division, Bureau of the Census and adjunct professor at the University of Maryland. He received a Ph.D. in mathematics from Brown University.

Ronald G. Douglas has been dean of physical sciences and mathematics for over three years and served two terms as chair of the Mathematics Department at the State University of New York, Stony Brook. He has served on various boards and committees in the mathematical sciences community concerned with research, teaching, and resources.

Frank L. Gilfeather is chair of the Department of Mathematics and Statistics at the University of New Mexico. He is a member of the Committee on Science Policy of the American Mathematical Society. In addition to other professional service, he recently spent four years in Washington, D.C., at the National Science Foundation and as director of the National Research Council's Board on Mathematical Sciences.

James Glimm is chair of the Department of Applied Mathematics and Statistics at the State University of New York, Stony Brook. He has served on the faculties of the Massachusetts Institute of Technology, Rockefeller University, and Courant Institute of New York University. Dr. Glimm is a member of the National Academy of Sciences. He received his Ph.D. from Columbia University.

Daniel Gorenstein is Jacqueline B. Lewis Professor at Rutgers University. He is the director of the National Science Foundation Science Technology Center in Discrete Mathematics and Computational Science. Dr. Gorenstein is a member of the National Academy of Sciences. He received his Ph.D. from Harvard University.

Phillip A. Griffiths is provost and James B. Duke Professor of Mathematics at Duke University as well as chair of the NRC's Board on Mathematical Sciences. He has also been a professor of mathematics at Harvard and Princeton Universities. Dr. Griffiths is a member of the National Academy of Sciences. He received his Ph.D. from Princeton University.

Jeffrey H. Hooper is the head of the Quality Theory and Technology Department at AT&T Bell Laboratories. He received a Ph.D. in operations research from Cornell University.

Frank C. Hoppensteadt is dean of the College of Natural Science at Michigan State University. He has served on the faculties of the University of Wisconsin and New York University. Dr. Hoppensteadt was chair of the Department of Mathematics at the University of Utah from 1982 through 1985.

Dean L. Isaacson is director of the Statistical Laboratory and chair of the Department of Statistics at Iowa State University. Dr. Isaacson has taught undergraduate and graduate courses in statistics and mathematics and has conducted research in martingales, stochastic integrals, and Markov chains. He received a Ph.D. in mathematics from the University of Minnesota.

Gerald J. Lieberman is professor of operations research and statistics at Stanford University. He has served as vice-provost and dean of graduate studies and research, associate dean of humanities and sciences, and was the founding chair of the Department of Operations Research at Stanford. Dr. Lieberman is a member of the National Academy of Engineering. He received a Ph.D. in statistics from Stanford University.

Calvin C. Moore is associate vice president for academic affairs in the Office of the President of the University of California, with responsibility spanning the nine campuses of the University of California system. He has been on the faculty of the Mathematics Department of the University of California, Berkeley. Dr. Moore has also served as dean of physical sciences and founding deputy director of the Mathematical Sciences Research Institute.

Ingram Olkin is professor of statistics and education at Stanford University. Previously he was professor of statistics at the University of Minnesota and Michigan State University, and president of the Institute of Mathematical Statistics. He received a Ph.D. in statistics from the University of North Carolina.

Walter R. Pirie has been on the statistics faculty at Virginia Polytechnic Institute and State University since 1970. He is chair of the American Statistical Association's Committee on Undergraduate Curricula in Statistics. Dr. Pirie received a Ph.D. in statistics from Florida State University.

Michael C. Reed is professor of mathematics at Duke University. He is an analyst who recently completed a second term as chair of the Mathematics Department at Duke.

Jerome Sacks is professor of statistics at the University of Illinois, Champaign-Urbana.

Jayaram Sethuraman is chair of the Department of Statistics at Florida State University. He is a member of the Committee on Applied and Theoretical Statistics (National Research Council) and of the Council of the Institute of Mathematical Statistics. Dr. Sethuraman received a Ph.D. from the Indian Statistical Institute.

James R. Thompson is a professor and the founding chair of the Department of Statistics at Rice University. Previously, he served on the faculty of the Department of Mathematical Sciences at Rice. Dr. Thompson is a fellow of the American Statistical Association and the Institute of Mathematical Statistics, and is an elected member of the International Statistical Institute. He received a Ph.D. in mathematics from Princeton University.

James A. Voytuk is director of the Mathematical Sciences in the Year 2000 (MS 2000) project at the National Research Council. Prior positions include associate executive director of the American Mathematical Society and executive officer in the Mathematical Sciences Department at Rensselaer Polytechnic Institute. He received his Ph.D. in mathematics from the Carnegie Institute of Technology.

APPENDIX B: COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES

Norman Hackerman (Chairman), Robert A. Welch Foundation
Robert C. Beardsley, Woods Hole Oceanographic Institution
B. Clark Burchfiel, Massachusetts Institute of Technology
George F. Carrier, Harvard University
Ralph J. Cicerone, University of California at Irvine
Herbert D. Doan, The Dow Chemical Company (retired)
Peter S. Eagleson, Massachusetts Institute of Technology
Dean E. Eastman, IBM T.J. Watson Research Center
Marye Anne Fox, University of Texas
Gerhart Friedlander, Brookhaven National Laboratory
Lawrence W. Funkhouser, Chevron Corporation (retired)
Phillip A. Griffiths, Duke University
Neal F. Lane, Rice University
Christopher F. McKee, University of California at Berkeley
Richard S. Nicholson, American Association for the Advancement of Science
Jack E. Oliver, Cornell University
Jeremiah P. Ostriker, Princeton University Observatory
Philip A. Palmer, E.I. du Pont de Nemours & Company
Frank L. Parker, Vanderbilt University
Denis J. Prager, MacArthur Foundation
David M. Raup, University of Chicago
Roy F. Schwitters, Superconducting Super Collider Laboratory
Larry L. Smarr, University of Illinois at Urbana-Champaign
Karl K. Turekian, Yale University