Report of the

Committee of Visitors

for the

Division of Mathematical Sciences
National Science Foundation

February 12–14, 2007

Submitted on behalf of the Committee by
Margaret H. Wright, chair

to

Tony F. Chan
Assistant Director
Mathematical and Physical Sciences

1 COV Charge, Organization, and Procedures

The 2007 Committee of Visitors (COV) for the Division of Mathematical Sciences (DMS) at the National Science Foundation (NSF) was charged by Dr. Tony F. Chan, Assistant Director of the Directorate for Mathematical and Physical Sciences (MPS), to address and prepare a report on:

- the integrity and efficacy of processes used to solicit, review, recommend, and document proposal actions;
- the quality and significance of the results of the Division's programmatic investments;
- the relationship between award decisions, program goals, and Foundation-wide programs and strategic goals;
- the Division's balance, priorities, and future directions;
- the Division's response to the prior COV report of 2004; and
- any other issues that the COV feels are relevant to the review.

Following NSF guidelines, the COV consisted of a diverse group of members representing different work environments (research-intensive public and private universities, primarily undergraduate colleges and universities, private industry, other Federal government agencies or laboratories, and non-U.S. institutions), gender, ethnicity, and geographical location. A list of COV members and their affiliations is given in Appendix A.

Before the meeting, members were supplied by means of public and password-protected Web sites with some of the data needed to perform our audit functions. These data included the previous COV report from 2004 and the DMS response; DMS annual reports for 2004–2006; and detailed information about the distribution of awards in DMS and its programs.

The COV met on February 12–14, 2007 at NSF. On the first morning, COV members were welcomed by Tony Chan, Assistant Director, Mathematical and Physical Sciences. Judith Sunley, Executive Officer, Directorate for Mathematical and Physical Sciences, then informed committee members about NSF's conflict of interest policy, emphasizing the special nature of the COV and the consequence that COV members would not be allowed to view proposal jackets with which they have a conflict of interest.

Peter March, DMS Director, presented an overview of DMS to the full committee and answered questions. The committee was then divided into three subcommittees, each of which met separately to examine proposals from a subset of the DMS disciplinary programs as well as proposals from the "Institutes, Interdisciplinary, Infrastructure, Workforce" (I/I/I/W) programs. The table below summarizes the programs reviewed by each group; the lists of COV members assigned to these groups appear in Appendix B. The COV chair, Margaret Wright, moved from subcommittee to subcommittee during the meeting.

Group	Disciplinary programs	I/I/I/W program
1	Computational Mathematics Topology Geometric Analysis	Institutes
2	Applied Mathematics Mathematical Biology Algebra, Number Theory, and Combinatorics Foundations	Infrastructure and Interdisciplinary
3	Analysis Probability Statistics	Workforce

At the beginning of the initial subcommittee meetings, relevant DMS program officers presented overviews of their programs and answered questions. After training in accessing the electronic jackets (e-jackets), subcommittee members proceeded with their audit function by carrying out a detailed review of a selection of proposals. (The selection process is described at the beginning of Section 4.)

Subcommittees were encouraged to, and did, request additional data as well as further meetings with program officers. Peter March, Deborah Lockhart (DMS Executive Officer), and DMS program officers were available for consultation throughout the entire COV meeting.

To summarize the audit results associated with its charge, the COV was asked to use the NSF 2007 COV template[1]. The COV answers to questions in the template are contained in Section 4. The COV was also asked to answer a list of six "additional questions" (designated as AQ1–AQ6) posed by DMS and MPS. The COV responses to these questions are given in Section 3.

On the third day of the meeting, the full COV met with Peter March and Deborah Lockhart to clarify certain issues and to check some factual matters. We then presented the expected highlights of our report privately to Tony Chan, who remained with the COV for a subsequent presentation of the expected highlights of the report to Peter March and Deborah Lockhart. Following a wide-ranging discussion of issues arising from the report, DMS program officers joined the COV for a further conversation.

Acknowledgment. The COV offers heartfelt thanks to Peter March, Deborah Lockhart, and DMS program officers for their hospitality and helpfulness during the COV. Their candor in discussing complicated and potentially controversial issues was extremely valuable, as was the provision of additional requested data on short notice. The COV is also very grateful to DMS and NSF administrative staff for their prompt and friendly assistance in matters ranging from computer system support to distribution of lunch.

[1]The current template will be superseded in the latter part of FY 2007.

2 Major COV Findings, Recommendations, and Concerns

Reflecting a unanimous COV view, we begin our report with praise for the excellence of DMS. The mathematical sciences research supported by DMS is outstanding; the DMS portfolio of institutes, workforce programs, infrastructure projects, and interdisciplinary research is well balanced and healthy; DMS has been actively working to support research that links the mathematical sciences with other sciences and engineering, and to create programs that support collaborative research; and DMS takes an appropriately active—often, the leading—role in shaping and implementing NSF-wide initiatives.

The remainder of this section summarizes major findings as well as some concerns and accompanying recommendations. We have included consensus views and views held by a large fraction of the COV membership, but we have not attempted to present every individual view. In light of the diversity in perspectives on the COV, it would have been inconceivable for all COV members to agree with each other on every issue or to be perfectly satisfied with all aspects of DMS. The COV's responses to the additional and template questions are reported in Sections 3 and 4.

The proposal review process.

DMS's proposal review process is fair, effective, and well managed, and the DMS portfolio of funded proposals is appropriate in the dimensions examined by the COV.

The COV strongly supports the use of review panels, supplemented when appropriate by mail reviews. We also have a favorable view of DMS's "equalization" process, in which a fraction of each program's budget is held back for participation in a general review at the end of each annual cycle. This process greatly increases the flexibility needed to manage each "mega-program" as a whole.

The strategy used by the Applied Mathematics program (and mentioned in the January 2007 DMS response to the 2004 COV) of having a "PI proxy"—a designated panelist who reads the panel summary draft from the viewpoint of the PI—is very appealing as a mechanism to improve feedback to principal investigators.

This COV, like several predecessor COVs, observes that the NSF "broader impacts" merit review criterion remains problematic. Despite many efforts by NSF and DMS to inform the scientific community, there is still confusion about the meaning of this term as well as ambiguity about its role in the proposal evaluation process. Our only suggestion is to urge DMS to be persistent in explaining this criterion to the community. For example, Peter March could write an article about "broader impacts" for mathematical society news publications. Although there is an NSF Website[2] that describes the criterion in some detail and gives general examples of how proposals might address it, this information is not widely known in the mathematical sciences community. Thus it would be useful for DMS to (i) include pointers to this Website in calls for proposals and (ii) provide examples illustrating both appropriate and inappropriate statements about the broader impacts criterion in mathematical sciences proposals.

The COV notes that the burden for identifying and obtaining support for innovative, high-risk proposals falls mainly on the program officers because panels tend, not surprisingly, to lean toward conservatism in times of flat budgets. The COV urges DMS to consider new ways to enable the

[2] `www.nsf.gov/pubs/gpg/broaderimpacts.pdf`

funding of such proposals. For example, panels could be asked to designate proposals as "innovative and high-risk" before making their final rankings; if not otherwise funded, these proposals could be set aside for consideration during the equalization process. A potential benefit of such a scheme is that it would provide a more objective way for NSF to measure the presence of innovative, high-risk projects in its research portfolio (template question A.4.3, Section 4).

Too much unfunded excellence.

In reviewing the selection of proposals for our audit function, COV members uniformly found a worryingly large number of excellent proposals that were not funded because of budget limitations. Although the NSF template (Section 4) asks for comments only on the portfolio of funded proposals, the COV is nonetheless unanimous in believing that the large number of high-quality but unfunded research projects needs to be mentioned as a major concern in our report. Based on this finding, the overall feeling of the COV is that, if DMS receives the expected budget increases, it would be desirable to increase the number of awards made.

To be clear, the COV as a whole does not believe that, *as a general policy*, DMS should make more, but smaller, awards. Some COV members are sympathetic to this view and favor, for example, the idea of restricting summer salary for very highly paid senior PIs in order to have more money for junior investigators. However, others disagree, believing that it is important for DMS to maintain an appropriately large average award size. (See the answers to template question A.4.2 in Section 4.) In this regard, COV members display the expected range of views in the mathematical sciences community on a perennial "hot button" topic.

Pipeline issues.

The COV has no doubt about the excellence of the DMS research portfolio. This was evident in the ease with which COV members produced instances of successful "outcomes", formerly known as "nuggets", for Section B of the COV template. (See Section 4.) Even so, the COV has concerns about the portfolio with respect to several "leaky pipeline" issues.

1. Recognizing that the issue is not new, the COV is seriously concerned with the relatively low success rates for new investigators. Several COV members suggested a special competition for first-time PIs, such as the "first grant" scheme[3] of the UK's Engineering and Physical Sciences Research Council (EPSRC). We acknowledge that any such program would need very careful thought by DMS as well as input from the mathematical sciences community.

2. The COV is unhappy with the lower-than-average success rates for women and underrepresented minorities. We realize that these are longstanding and difficult problems to which NSF has devoted significant attention and resources, but it is our duty to highlight this recurring concern once again. (We also note the extensive responses to template question A.4.11 in Section 4.)

   The Biology Directorate at NSF has two forms of special awards, Research Initiation Grants and Career Advancement Awards, to broaden participation in the biological sciences for underrepresented minorities. DMS might consider similar programs and/or a separate strategy for faculty at undergraduate institutions that are primarily minority-serving. Such faculty

[3] `www.epsrc.ac.uk/ResearchFunding/Opportunities/NewAcademics/FirstGrant/default.htm`

often face not only very demanding teaching loads, but also institution-wide administrative policies that discourage external research grants.

The COV supports the suggestion for longitudinal studies of underrepresented minority students made by Subcommittee 2 in response to question AQ1 (Section 3).

3. A third serious concern of the COV is the decreasing absolute level of support for Ph.D. students, since adequate research support for Ph.D. students is essential to the attractiveness of the mathematical sciences as a career. We make two related recommendations: (i) that DMS investigate the causes of the drop in Ph.D. student support, and (ii) that DMS consider the mechanisms for Ph.D. student support across its portfolio, in the spirit suggested by Subcommittee 3 in its response to question AQ6 (Section 3).

4. Several COV members stressed the importance of encouraging research engagement by faculty from primarily undergraduate institutions, especially institutions that are primarily minority-serving. In this regard, see the response of Subcommittee 1 to questions AQ3 (Section 3) and A.4.8 (Section 4).

A suggestion made during the plenary COV discussion was that these pipeline issues might be partially addressed through an increase in the "workforce" part of the DMS budget—currently, the EMSW21[4] programs (Enhancing the Mathematical Sciences Workforce of the 21st Century).

The DMS institute portfolio.

The COV response to question AQ2 (Section 3) makes clear that the COV takes a very positive view of the mathematical sciences institutes. But there is an unfinished task that DMS needs to carry out (see question AQ1, Section 3): an analysis of the complete portfolio of institute activities (programs, workshops, and conferences), considering at least the following questions:

1. how these activities are related to DMS's research portfolio;
2. whether institute activities appropriately express the dynamic balance among core and emerging areas in the mathematical sciences;
3. how well institute activities reflect emerging research opportunities at both the interfaces between core areas of mathematics and the interfaces of mathematics with other disciplines; and
4. the balance of short-term workshops/conferences with longer (one-semester or one-year) programs.

This analysis should be done as soon as possible, well before the next round of institute competition, because so many aspects of the institutes have changed during the past few years. A summary of the analysis should be made available to the mathematical sciences community, perhaps as part of the DMS response to this COV report.

[4]The EMSW21 programs comprise VIGRE (Vertical Integration of Research and Education), RTG (Research Training Groups), and Mentoring through Critical Transition Points (MCTP).

Communication with the mathematical sciences community.

Although DMS is certainly aware of this point, we note for the record our consensus view that clear and frequent communication with the mathematical sciences community is crucial for DMS. The presence of DMS staff at scientific meetings is welcome and important, but we also suggest that DMS staff write regular articles for the news publications of mathematical societies. In addition, it might be possible for DMS to make creative use of the Web—for example, by providing and publicizing a Website for receiving ideas and suggestions from the community.

Measuring the impact of student and postdoc support.

To provide quantitative documentation of successes in training the next generation of mathematical scientists, the COV urges DMS to track the career paths of (i) undergraduates who receive REU support from DMS and (ii) DMS-funded Ph.D. students and postdocs. We recognize that privacy issues are non-trivial, but believe that it is important to confirm anecdotal evidence about the positive effects of DMS support and to gain insight about the nature of the most effective programs.

3 Additional Questions for the COV

This section contains the COV's responses to the six "additional questions" posed by DMS and MPS, designated here as AQ1–AQ6. When there was a consistent view among the three groups, a unified response is given. When the groups expressed substantially different opinions, their views are labeled and stated separately.

Overall concerns derived from the COV's discussion of these questions have been marked with "*" in this section and included in Section 2.

AQ1. Please comment on the response by the Division of Mathematical Sciences to the previous Committee of Visitors report.

*__Group 1.__ The 2004 COV expressed concern "that core components of the mathematical sciences are not receiving adequate attention and resources in the overall work of the NSF institutes" and recommended that DMS "carefully evaluate this question and actively respond if appropriate". Although the DMS response of March 2004 mentioned a then-ongoing internal analysis of institute programs, that analysis was not made available to the previous COV, nor to the present one. The sense of plenary COV discussions was that this issue needs to be revisited.

Group 2. Overall, the general feeling of Subcommittee 2 was that the DMS response to the 2004 COV report was comprehensive, thoughtful, and sincere. The recommendation in the 2004 COV report about improving the balance between rotators and permanent program officers was dealt with particularly well.

*Subcommittee 2 noted one important area in which DMS has not continued to update its response. The 2004 COV report contained differing views about whether there is an appropriate level of participation by underrepresented groups; DMS responded in March 2004, but not in subsequent years. This issue, which is universally acknowledged to be complicated and difficult, generated significant discussion in all three subcommittees in the present COV (see question A.4.11 in Section 4). It may be helpful to carry out a longitudinal study of data to try to determine strategies and "best practices" that lead to future participation by minority students in NSF programs. Such studies could be done as part of administering DMS's EMSW21 workforce programs, in collaboration with outside programs that encourage minority participation in mathematics, such as Enhancing Diversity in Graduate Education (EDGE), and/or with organizations such as the National Association of Mathematicians (NAM) and the Society for Chicanos and Native Americans in Science (SACNAS).

Group 3. Subcommittee 3 thought that the DMS response adequately addressed the concerns of the previous COV. In particular, the requested evaluation of the VIGRE program is underway, and a common portal for the institutes has been implemented.

AQ2. Please comment on the size, scope, and effectiveness of the portfolio of national mathematical sciences institutes.

The COV believes that the institutes are a valuable asset to the mathematical sciences community. Institute programs provide a rich variety of forums that allow mathematics research to reach a wide audience of mathematical scientists and those in related fields. COV members noted that institutes not only organize a variety of research programs, but are also involved in outreach to underrepresented groups and to the non-mathematical community at large.

The overall view of the COV is that the balance in the DMS budget between the institutes and other programs is appropriate.

The COV believes that it would be inadvisable to assign a rigid set of topics to each institute, but equally inadvisable to expend scarce DMS resources on multiple programs with an unduly large overlap. We therefore commend DMS for regarding the institutes as part of a portfolio of activities, and for encouraging coordination and collaboration among the institutes. We recommend that DMS continue this process.

The question of possible expansion of the institute program was discussed briefly, but no general conclusions were reached. Several COV members felt that expansion can be revisited as new needs become apparent and if additional funding becomes available. In the latter case, there was some support for the idea that DMS funding for international mathematics institutes should be increased.

Finally, a few COV members are deeply concerned about the flat rate of funding for the Mathematical Sciences Research Institute (MSRI) during the past 10 years, which represents a decrease of approximately 18% in real dollars compared to 1997 funding. Some of this concern is linked to the issue raised by the previous COV of representation of "core components of the mathematical sciences" in institute programs. It is also relevant to the need for the analysis of institute activities requested by this COV (see Section 2).

AQ3. Please comment on the size of DMS grants and on the tradeoff between grant size and number of grants.

*Members of all three subcommittees noted the large number of excellent proposals that could not be funded because of budget limitations. As a result, a general COV view was that serious consideration should be given to increasing the number of awards if the expected DMS budget increases occur.

Group 1. Members of Subcommittee 1 felt that the needs of faculty in predominantly undergraduate institutions could be better addressed, particularly at institutions that are primarily minority-serving. For example, small grants could be provided for teaching buyouts or visits to mathematics institutes. In this connection, it was noted that few proposals are either submitted to or funded by the Research in Undergraduate Institutions (RUI) program. (Also see the response of Subcommittee 1 to question A.4.8 in Section 4.)

One suggestion for increasing the number of researchers receiving funding from DMS was to expand support for travel grants, possibly administered by the American Mathematical Society, to enable the broadest spectrum of the mathematical community to participate in research and bring its excitement back to their students.

Group 2. Given the budget constraints, the current award sizes represent a reasonable compromise between the number and size of awards. We encourage providing substantial graduate student support to established researchers with excellent records as PhD supervisors. The use of grant supplements for additional graduate student support is one appropriate mechanism for accomplishing this. In supporting postdoctoral associates it is important to maintain proper balance between mentorship and intellectual freedom. The program officers should be commended on their thoughtful and careful distribution of funds given the present financial constraints of the program. Programs such as the Conferences, Workshop, and Special Meetings programs provide important travel opportunities that greatly stimulate the mathematical community.

***Group 3.** Subcommittee 3 recognizes the arguments in favor of increasing the size of awards, and some progress toward that goal was made during the period under review. We feel that now a higher priority should be placed on increasing the number of supported investigators. Currently many highly rated proposals are declined due to a lack of sufficient funds in the DMS budget.

AQ4. Is the current structure of subfields within DMS (i.e. Algebra, Number Theory and Combinatorics, Computational Mathematics, etc.), which has been in use for many years, still adequate in responding to changes in the field? What specific modifications would the COV suggest?

The overall view of the COV was that the current subfield structure works well and therefore there is no need to change it. In this regard, we noted that DMS is responsive to changes and emerging areas in the mathematical research landscape. For example, the recent creation of a new subprogram in Mathematical Biology reflects the growing importance of this field.

AQ5. Is the portfolio of research supported by DMS providing enough collaborative opportunities between the mathematical sciences and other fields, both within NSF and in other federal funding agencies?

The COV was very favorably impressed by DMS's efforts to expand collaborations with other programs within MPS and more broadly within NSF, including joint programs with the directorates of Biology, Computer and Information Science and Engineering (CISE), Engineering, and Geosciences—for example, "Innovations at the Interface with Computer Science" and "Collaborations in Mathematical Geosciences".

The COV also commends DMS for pursuing collaborative opportunities with other federal agencies such as the Department of Defense, the Department of Energy, intelligence and security agencies, and the National Institutes of Health—for example, the mathematical biology initiative sponsored by DMS and the National Institute for General Medical Sciences.

The COV hopes that DMS will continue to be active in creating and seeking collaborative opportunities for the mathematical sciences. In particular, the newly announced Cyber-enabled Discovery and Innovation (CDI) initiative offers promise for new connections both within NSF and with other agencies.

AQ6. Given the NSF strategic outcome goals of Discovery, Learning, and Research Infrastructure, formerly Ideas, People, and Tools[5], please comment on the balance of the Division's award portfolio among individual investigator awards, collaborative or small group grants, workforce, infrastructure, and institute awards. In addition, please comment on the impact of the Mathematical Sciences Priority Area (MSPA) on portfolio balance.

The overall COV view was that NSF's Mathematical Sciences Priority Area (MSPA) has had a positive effect. The major effects of the MSPA on portfolio balance, summarized in Peter March's initial presentation to the COV, were to increase the percentages of the portfolio devoted to interdisciplinary research (4% to 14%) and workforce programs (11% to 16%), and to reduce the percentage for programs labeled as "core" (from 68% to 56%). Based on the importance of mathematical sciences research to science and engineering and the documented inadequacy of support for mathematics and statistics, the MSPA has led to absolute growth in core disciplines, interdisciplinary activities, and workforce and infrastructure projects. Since its "jumpstart" in 2002, the MSPA produced a sizeable increase in the DMS budget (from $121 million to $200 million), and to an increase of DMS funding for core areas of mathematics from $82 million to approximately $112 million.

Groups 1 and 2. Among the members of subcommittees 1 and 2, there was general agreement that DMS has done a good job with the difficult task of producing a balanced investment of its portfolio of resources.

Group 3. The perspective of Subcommittee 3 on the balance of the award portfolio focused on two concerns: (i) that DMS should review its current implementation of support for graduate students and postdocs, and (ii) that there should be fairness and equity in funding postdocs under individual investigator awards and workforce programs. Issue (i) is related to an overall COV concern with funding of graduate students, the third of several pipeline issues discussed in Section 2.

*Subcommittee 3 observed that graduate students are supported in many different ways, including research grants and various workforce programs. This variety could be viewed either as laudable flexibility and diversity in achieving a goal or as an unfocused and somewhat haphazard approach. The subcommittee was uncertain about precisely what target DMS is aiming at in supporting graduate students: is the goal principally to address national workforce needs, or are there other considerations too? It would be useful to take a systematic look at the support of graduate students and postdocs to determine the best way to allocate resources to these groups.

A particular concern of Subcommittee 3 involved support for postdocs in the Focused Research Group (FRG) program. Although members of Subcommittee know examples of successful FRG awards, we also know examples of postdocs who were not competitive for Mathematical Sciences Postdoctoral Research Fellowship awards, but who were supported as part of FRG grants. Such instances were viewed as troubling on grounds of fairness and equity. Subcommittee 3 felt that resources devoted to FRG awards could have wider impact if distributed to individual researchers instead.

[5]The latter three are the names used in the 2007 COV Template provided to this COV.

4 Audit Summary and Template

The three groups referred to in the responses to the template questions are defined in Section 1 and Appendix B.

Date of COV: February 12–14, 2007

Division: Mathematical Sciences

Directorate: Mathematical and Physical Sciences

Number of actions reviewed by Group 1. ∼180	**Awards: ∼70**	**Declinations: ∼110**
Number of actions reviewed by Group 2. ∼240	**Awards: ∼100**	**Declinations: ∼140**
Number of actions reviewed by Group 3. ∼280	**Awards: ∼110**	**Declinations: ∼170**

Total number of actions within the Division of Mathematical Sciences during period under review.

Awards: 2564 Declinations: 5163

Manner in which reviewed actions were selected: The jackets reviewed by the COV were chosen in three stages. First, for the disciplinary, interdisciplinary, infrastructure, and workforce programs, a random selection was made by an administrative staff member of approximately equal numbers of awards and declinations from each of the three fiscal years under review. All current institute jackets were made available to Group 1. DMS program officers then added jackets that were "interesting" and/or that presented a "balanced" picture of the program, reflecting "borderline" or difficult cases, high-impact awards, mixes of junior and senior investigators, and so on. Finally, during the COV, each subcommittee requested at least 20 additional jackets.

For the reader's convenience, we include a list of frequently used acronyms.

- CAREER: Faculty Early Career Development Program
- EMSW21: Enhancing the Mathematical Sciences Workforce of the 21st Century
- FRG: Focused Research Group
- MCTP: Mentoring through Critical Transition Points
- REU: Research Experiences for Undergraduates
- RTG: Research Training Group
- RUI: Research in Undergraduate Institutions
- VIGRE: Vertical Integration of Research and Education

PART A. Integrity and Efficiency of the Program's Processes and Management

A.1. Quality and Effectiveness of Merit Review Procedures	
A.1.1. Is the review mechanism appropriate? (Panels, ad hoc reviews, site visits)	
Group 1. We support the move toward using panels whenever possible.	Yes
Group 2. The subcommittee was enthusiastic about the panel review system. It felt that panels helped standardize the feedback received by the PI. The subcommittee also felt that the discussion generated during panel meetings was useful for evaluating the quality of the proposals and resulted in a ranking of the proposals that was more accurate than mail reviews provided.	Yes
Group 3. The mechanism of panel reviews supplemented by mail reviews is appropriate for the programs under evaluation. Subcommittee 3 noted approvingly that certain programs had discontinued the use of pre-screening panels. A small number of proposals receive mail reviews only, and the subcommittee would prefer to see all proposals handled by a panel, supplemented by mail reviews when necessary.	Yes
A.1.2. Is the review process efficient and effective?	
Group 1. Effectiveness depends on judgment of the program officers (e.g., soliciting e-mail reviews where panel expertise is inadequate), and seeking input from more than one panel. The program officers do a very good job in this regard.	Yes
Group 2. It was felt that the panel review system is more efficient than the mail system, and that it results in more accurate evaluation of the proposals.	Yes
Group 3.	Yes
A.1.3. Do the individual reviews (either mail or panel) provide sufficient information for the Principal Investigator(s) to understand the basis for the reviewer's recommendation?	
Group 1. On the whole, yes. But anything that could be done to improve reviewer feedback to the PIs would be worth the effort.	Yes
Group 2. The subcommittee noted that there is a wide variation in the quality of feedback individual reviewers provide to the PI. In some cases the reviews were felt to be too terse or uninformative. In other cases they laid out carefully the strengths and weaknesses of the proposal.	Usually
Group 3. The majority of the reviews read by Subcommittee 3 did give valuable feedback to the Principal Investigators. In some cases, however, the reviewers insufficiently explained the rationale for their assessment.	Yes

A.1.4. Do the panel summaries provide sufficient information for the Principal Investigator(s) to understand the basis for the panel recommendation?	
Group 1. Panel summaries can be sketchy at times. It would be good to improve this for the borderline cases.	Yes/No
Group 2. Generally the subcommittee felt that the panel summaries provided good feedback to the PI and helped put the individual reviews in context. Some programs seem to provide more detailed information than others. The Applied Math Program, perhaps because of the "PI proxy" process and the explicit listing of proposal strengths and weaknesses, was felt to provide particularly good feedback in the panel summaries.	Yes
Group 3. The panel summaries were informative, fair, and balanced. More detailed information about the actual rankings by the panel would be helpful to the PI in some cases. In the Mathematical Sciences Postdoctoral Research Fellowship (MSPRF) program, the PI receives essentially no information about the basis for the decision, which is probably appropriate in this case. On the other hand, the internal panel summaries for the MSPRF program are astonishingly detailed and reveal that the review process is thorough and thoughtful.	Yes

A.1.5. Is the documentation for recommendations complete, and does the program officer provide sufficient information and justification (a) for her/his recommendation? (b) for the Principal Investigator(s)?	
Group 1. The subcommittee thought that this was well done.	Yes
Group 2. The jackets provided clear information about how the Program Officer reached his or her decision. There was concern by some subcommittee members that the information provided to the PI was not sufficiently specific and that more detailed information would help the PI revise a rejected proposal. However, other subcommittee members felt that the panels and program officers should not "micromanage" resubmissions.	Yes
Group 3. The internal review analyses by the program officers were consistently excellent and informative. Subcommittee 3 noted that certain program officers were especially effective at communicating to the Principal Investigator the rationale for funding decisions. In some cases of declinations, the program officers gave good suggestions to the PI about how to improve future proposal submissions. In a few isolated cases, the available documentation was insufficient for the subcommittee to understand discrepancies between panel rankings and the ultimate disposition of awards.	Yes

A.1.6. Is the time to decision (dwell time) appropriate?	
Group 1. We noted that the average time is shortening, which is good.	Yes
Group 2. The subcommittee was impressed by the trend toward handling essentially all proposals within six months.	Yes
Group 3. Given the complexity of the task, the process seems to be expeditious.	Yes

A.1.7. Additional comments on the quality and effectiveness of the program's use of merit review procedures.

Group 2. It would be helpful if, in addition to providing proposal guidelines, examples of best practices for proposal writing were widely distributed, including being prominently linked to the proposal guidelines Web page. This would complement workshops that are held at national meetings.

Group 3. In general, we are very satisfied with the quality of the process.

A.2. Implementation of the NSF Merit Review Criteria (Intellectual Merit and Broader Impacts)	
A.2.1. Have the individual reviews (either mail or panel) addressed both merit review criteria?	
Group 1. Yes, with respect to intellectual merit. Sometimes, however, individual reviews did not adequately address the broader impacts criterion.	Yes/No
Group 2. There was wide variation and inconsistency in how individual reviewers addressed the broader impacts criterion. This occurred across all programs reviewed by this subcommittee.	Sometimes
Group 3. The reviews of research proposals typically give thorough discussion of intellectual merit, but the broader impacts criterion often is discussed only in a cursory way, especially when the proposal itself treats broader impacts briefly. In the workforce programs, on the other hand, where broader impacts play a dominant role, the discussion of this criterion is more extensive.	Yes
A.2.2. Have the panel summaries addressed both merit review criteria?	
Group 1.	Yes
Group 2. The panel summaries consistently addressed both merit review criteria.	Yes
Group 3.	Yes
A.2.3. Have the review analyses (Form 7s) addressed both merit review criteria?	
Group 1.	Yes
Group 2. The review analyses consistently addressed both merit review criteria.	Yes
Group 3. We commend the project officers for the excellent job they do given the time constraints inherent in the review process.	Yes

A.2.4. Additional comments with respect to implementation of NSF's merit review criteria.

Group 1. The evaluation of broader impacts was inconsistent, and an understanding of this criterion is still evolving (even among program officers). NSF should keep working on establishing well-defined criteria.

Group 2. The "broader impacts" criterion generated more discussion than any other single topic in our subcommittee's discussions. There was concern that it is still not clear to either PIs or reviewers what should be included in this category or how it should be weighted. This may not be the fault of the Foundation but nonetheless, this confusion still exists. We did note that the Program Officers are careful to address the broader impacts criterion in their analyses.

Group 3. The criterion of "broader impacts" is not well understood by the mathematical community. It is unclear how much weight this criterion has in funding decisions for research proposals. Continued outreach efforts by NSF staff to explain to the community the meaning and significance of the "broader impacts" merit review criterion would be useful.

A.3. Selection of Reviewers	
A.3.1. Did the program make use of an adequate number of reviewers?	
Group 1.	Yes
Group 2. The number of reviewers was felt to be appropriate in all cases reviewed by the subcommittee.	Yes
Group 3. Most panels that Subcommittee 3 studied had at least ten panelists, which is a large enough number to cover a good range of expertise.	Yes
A.3.2. Did the program make use of reviewers having appropriate expertise and/or qualifications?	
Group 1. Program officers work hard to find appropriate reviewers, but occasionally a proposal only gets one expert reviewer.	Yes
Group 2. The subcommittee was impressed by the quality of the panels. We applaud the program officers for obtaining additional mail reviews in those rare cases where certain specializations were not represented.	Yes
Group 3. Subcommittee 3 was pleased with the cases that we analyzed.	Yes
A.3.3. Did the program make appropriate use of reviewers to reflect balance among characteristics such as geography, type of institution, and underrepresented groups?	
Group 1. We commend the efforts to compose balanced panels.	Yes
Group 2. In general the panels seemed to have an appropriate balance of panelists from different regions, institutions and underrepresented groups. However, in spite of the active efforts of the program directors to balance the panels, the subcommittee did note that women continue to be underrepresented on some panels.	Yes
Group 3. The program officers are commendably effective in assembling diverse panels of reviewers.	Yes
A.3.4. Did the program recognize and resolve conflicts of interest when appropriate?	
Group 1.	Yes
Group 2. The subcommittee felt that in all cases conflicts of interest were handled appropriately.	Yes
Group 3. We were very pleased with the way this issue was addressed.	Yes

A.3.5. Additional comments on reviewer selection.

Group 1. In Computational Mathematics, better use of expertise from industry and the national laboratories is suggested.

Group 2. The subcommittee was dismayed to learn that acceptance rates for panelists are often as low as 25%.

Group 3. We recognize that reviewer selection is a difficult job; the program officers have been very effective at carrying out this task.

Group 3 was dismayed to learn from program officers that a significant percentage of potential reviewers who are asked to participate on panels decline to serve. There was some discussion of the feasibility of off-site review panels and of possible outreach activities to educate the community about the importance and the value of serving on review panels.

A.4. Portfolio of Awards	
A.4.1. Overall quality of the research and/or education projects supported by the program.	
Group 1. The overall quality of the funded proposals was very high.	Appropriate
Group 2. Outstanding.	Appropriate
Group 3. Subcommittee 3 was very impressed by the projects supported. The major concern was the number of excellent projects that could not be supported because of insufficient funds in the budget.	Appropriate
A.4.2. Are awards appropriate in size and duration for the scope of the projects?	
Group 1. Subcommittee 1 believes that there should be more awards to junior faculty and more support for postdocs and graduate students. Some members of the group believe that situation could be ameliorated if NSF were to restrain summer salary awards to highly paid senior faculty.	Appropriate
Group 2. For the core areas the size and duration are appropriate. A larger number of higher awards would be desirable but in the current context of tight budgets this is likely to be unrealistic and we feel that the program officers are doing a good job of balancing the size and duration of the awards.	Appropriate
Group 3. Overall, Subcommittee 3 thought that the size and duration of awards were appropriate, although there were particular cases where the subcommittee would have disagreed with the program officer's decision. The subcommittee was in favor of five-year awards to high-impact research projects. There was, however, concern about the size of some of the larger grants, on the grounds that concentrating too much of the limited resources in a few projects is not good for the community. In particular, there was a belief that there should be a ceiling on the amount of summer salary awarded. Also, for projects with multiple senior PIs, it was felt that each PI should be evaluated separately.	Appropriate (but see comments)

A.4.3. Does the program portfolio have an appropriate balance of innovative high-risk projects?	
Group 1. Young people with no track record are in some sense high-risk, and they do not seem to be funded at an appropriate level. Also, few innovative projects seem to be funded.	Mostly appropriate
Group 2. It appeared that, although the panels can be conservative in rating higher-risk proposals, the program officers do a good job of collecting information and identifying valuable high-risk opportunities for funding. For example, in one case an innovative proposal that was not put at the top of the panel's ranking was sent out for further mail review; the project was then funded and led to a significant advance in number theory.	Appropriate
Group 3.	Appropriate

A.4.4. Does the program portfolio have an appropriate balance of multidisciplinary projects?	
Group 1. In Computational Mathematics, surprisingly few multidisciplinary proposals were either submitted or funded. In Geometry, there are some interesting multidisciplinary projects. The Institutes have a very good mix of multidisciplinary activities.	Mostly appropriate
Group 2. Subcommittee 2 was impressed by the balance of multidisciplinary projects in the portfolio.	Appropriate
Group 3.	Appropriate

A.4.5. Does the program portfolio have an appropriate balance of funding for centers, groups and awards to individuals?	
Group 1. Members of Group 1 had differing opinions about this topic. Additional question AQ6 is very similar; see Section 3 of the report.	Mostly appropriate
Group 2.	Appropriate
Group 3. Subcommittee 3 felt that the balance between workforce programs and disciplinary programs was appropriate. Subcommittee 3 did not look at the institutes program and therefore did not discuss whether the amount of money allocated to centers is appropriate.	Appropriate

A.4.6. Does the program portfolio have an appropriate balance of awards to new investigators?	
Group 1. Group 1 felt that the success rates of proposals from new investigators are too low.	Not appropriate
Group 2. The program officers do a good job of ensuring that panels balance new investigators and more established researchers.	Appropriate
Group 3. The data show that the age demographics of those supported are well balanced. In the field of probability, the awards were well correlated with the ranking of the panels, but there seemed to be few grants to younger researchers.	Appropriate (but see comment)

A.4.7. Does the program portfolio have an appropriate geographical distribution of Principal Investigators?	
Group 1.	Appropriate
Group 2.	Appropriate
Group 3. Subcommittee 3 noted no problems in this area.	Appropriate

A.4.8. Does the program portfolio have an appropriate balance of institutional types?	
Group 1. The conference awards are well distributed. We observed that the rate of funding for proposals to the RUI program is rather low. In part this seemed to be because RUI proposals, even when deemed worthy of funding, were not competitive with the overall set of proposals considered by a given panel. If DMS funding increases, it might be appropriate for program officers to set aside highly ranked but unfunded RUI proposals for review as part of the year-end equalization process.	Mostly appropriate
Group 2. Subcommittee 2 recognizes the challenge of recruiting high quality RUI proposals.	Appropriate
Group 3. The research grants by their nature go mostly to research universities. Projects funded by the Research Experiences for Undergraduates (REU) and MCTP programs have a nice balance of research institutions and four-year colleges.	Appropriate

A.4.9. Does the program portfolio have an appropriate balance of projects that integrate research and education?	
Group 1. The amounts of support for graduate students varied significantly. It was hard to tell whether this was random or a result of NSF's decision to maintain PI salaries.	Appropriate
Group 2. The REU, RTG, MCTP and VIGRE programs are doing a good job of integrating research and education. However, Subcommittee 2 noted with concern the decline in the number of graduate students supported by DMS during the period under review (which was probably caused by the combination of inflation and flat budgets).	Appropriate
Group 3.	Appropriate

A.4.10. Does the program portfolio have an appropriate balance across disciplines and subdisciplines of the activity and of emerging opportunities?	
Group 1. DMS is doing a fine job in this regard. (Further details are given in our answers in Part B.) We commend DMS for encouraging research in innovative areas—for example, through "Dear Colleague" letters to stimulate proposals on stochastic systems ("Cross-cutting Topics on Stochastic Systems"; NSF05-039) and design of numerical methods that remain accurate after many steps and when implemented in heterogeneous large-scale computing environments ("Long-Time Behavior of Numerical Methods in Large-Scale Scientific Computing"; NSF07-002).	Appropriate
Group 2. The funding "equalization" exercise described by the program officers seems to create a good balance across disciplines and subdisciplines.	Appropriate
Group 3. The program officers seem well aware of important disciplinary developments and are able to adapt to emerging trends. For example, the analysis program now identifies random matrix theory as an important subdiscipline, reflecting the exciting work in this area in the last decade.	Appropriate

A.4.11. Does the program portfolio have appropriate participation of underrepresented groups?	
Group 1. This is always a problematic issue. We commend the use of the equalization process for this purpose. If more young investigators can be funded, the proportion of underrepresented groups could also be increased.	Appropriate
Group 2. Subcommittee 2 felt that the funded program portfolio is appropriate to the pool of submitted proposals. The subcommittee would like to have seen more participation of women and minorities while recognizing that the current level reflects known broader pipeline issues in science. We note for the COV record that in 2004, 2005, and 2006, the the percentages of female applicants are 12%, 12%, and 14%, and the percentages of minority applicants are 4.7%, 5.0%, and 5.4%. In 2004, 2005, and 2006, the success rates for women are 25%, 29%, and 27%; the success rates for minorities are 21%, 31%, and 28%; and the success rates for men are 32%, 30%, and 32%. The overall success rates for research proposals in 2004, 2005, and 2006 are 29%, 32%, and 30%.	Appropriate
Group 3. Subcommittee 3 was particularly interested in this issue and was pleased to see some successes in the analysis, statistics, and workforce programs. Subcommittee 3 expressed concern about the very small number of women supported by the probability program and the low success rate (approximately 15%) for proposals from women PIs in this program in 2006. As in the case of age demographics, program officers followed the recommendations of the review panels. The subcommittee did, however, identify some declined proposals from women that appeared to be worthy of funding if additional funds had been available. The cognizant program officer indicated that the funding decisions in that competition had been difficult. The total number of proposals from female investigators to the probability program is too small to allow statistically significant conclusions, and we were also informed that some proposals from the same cohort of female investigators were successful in the current year's competition. Nonetheless, we encourage increased outreach efforts to increase the number of submissions from women PIs. The success rate for proposals from female investigators was significantly higher in the analysis program than in most other programs. The program officers in analysis indicated that diversity was an issue to which they had devoted special attention. Propagating their best practices to other programs could be useful. The small number of mathematical scientists from racial and ethnic minorities continues to be a challenge for the mathematics community. Some members of Subcommittee 3 lamented the lack of substantial progress in increasing the participation of such underrepresented groups in the DMS portfolio.	Appropriate (but see comments)

A.4.12. Is the program relevant to national priorities, agency mission, relevant fields and other customer needs?	
Group 1. The DMS response to the NSF-wide Mathematical Sciences Priority Area (MSPA) is appropriate.	Yes
Group 2. The examples from section B illustrate the contributions of research supported by the DMS to a variety of national needs.	Yes
Group 3.	Yes

A.4.13. Additional comments on the quality of the projects or the balance of the portfolio.
Group 2. Subcommittee 2 was extremely impressed by the quality of the funded research.

A.5. Management of the Program Under Review

A.5.1. Management of the program.

Group 1. Program officers are working hard, and doing a very good job. The e-jackets are very helpful to the review and COV oversight process.

Group 2. All programs are managed very well. We commend the DMS for its successful efforts in appointing additional permanent program officers. Such appointments provide stability, consistency and institutional memory in program management.

Group 3. Subcommittee 3 was impressed with the professionalism of the DMS staff. The subcommittee supports the division's effort to find a permanent program officer for the statistics and probability program to balance the rotators.

A.5.2. Responsiveness of the program to emerging research and education opportunities.

Group 1. Program officers are very open to new ideas, and are alert to creating new connections. In Computational Mathematics, there should be initiatives in emerging areas such as multiscale modeling and analysis, or uncertainty quantification.

Group 2. We commend the DMS on its responsiveness to emerging research opportunities, in particular in its creation of the Mathematical Biology program. Similarly the RTG, MCTP and Special Meetings programs respond to education opportunities.

Group 3. The workforce program provides numerous opportunities for innovative proposals in education.

A.5.3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

Group 1. The planning is a team effort, and the current process is yielding good results. We commend the policy of holding back 10% of each program's budget for equalization. If the DMS budget increases, it might be appropriate to increase this percentage to improve the success rates for high-risk proposals, proposals from junior investigators or RUI proposals.

The program officers are flexible, and we welcome the lack of quotas for specific areas; DMS treats its portfolio as a whole.

Group 2. This process is very effective.

Group 3. Subcommittee 3 did not observe nor see a need for detailed planning in the development of the research portfolio. The current policy seems to be to arrange efficient and effective evaluation of the proposals that are submitted. The subcommittee finds this procedure reasonable, as it allows for adapting to new research trends and natural fluctuations from year to year.

A.5.4. Additional comments on program management.

Group 1. Subcommittee 1 was impressed by the level of commitment, dedication, imagination and knowledge of the DMS program officers.

Group 2. Very well managed.

PART B. Results of NSF Investments

Note: The responses in Part B represent a combination of the views of Groups 1–3 about notably successful "outcomes" supported by DMS.

B.1. Outcome Goal for People: Developing a "diverse, competitive, and globally engaged workforce of scientists, engineers, technologists and well-prepared citizens".

DMS has done an excellent job of stimulating the training and development of mathematical scientists at all levels. The entire VIGRE initiative is a gem in the DMS workforce portfolio. Nationally, VIGRE awards have transformed undergraduate and graduate education in mathematics at many institutions. The associated programs emphasize active learning, early exposure to research, and collaboration between undergraduates, Ph.D. students, and postdoctoral and regular faculty.

The first phase of the VIGRE program identified successful and innovative graduate programs; the subsequent EMSW21 initiatives (RTG, MCTP and the new VIGRE) show that DMS is continuing to support exciting programs for training our young workforce. The COV is very supportive of these initiatives, the quality of the programs they are producing, and the continuation of this direction of support.

The COV also notes the important support provided by NSF to undergraduate institutions through RUI grants. These institutions produce excellent graduate applicants and provide many research opportunities for undergraduates. Finally, the CAREER award program puts important resources into stimulating the research of junior faculty as well as involving them in training of future students.

We list three instances of DMS-supported programs displaying excellence in the "people" outcome goal.

1. The VIGRE program at the University of Chicago (DMS-0502215) was recently renewed, reflecting the program's outstanding first five years. This program has many innovative components, including elements aimed at Chicago-area high school students (the Young Scholars Program, or YSP) and at Chicago public school teachers (SESAME), most intensively during the summer. With VIGRE support, Chicago initiated an REU summer program in which undergraduates, primarily mathematics majors, both learn new mathematics that is not part of the standard curriculum and teach in the YSP and SESAME programs. The dual nature of the REU has proven to be spectacularly and unexpectedly popular and successful. Over seven per cent of BA degrees at the University of Chicago are given in mathematics, and an increasing percentage of these graduating seniors are going on to graduate study in mathematics.

2. The Center for Women in Mathematics at Smith College (DMS-0611020) is an innovative program to prepare women with non-traditional backgrounds to pursue graduate degrees in mathematics. This program fills a need that no other program has yet addressed. Information learned during the course of this grant can be used to replicate the program at other institutions, with other underrepresented groups, and in other fields.

3. The IMMERSE (Intensive Mathematics: a Mentoring, Education, and Research Summer Experience) program is the centerpiece of an MCTP award (DMS-0354281) to the University of Nebraska at Lincoln. IMMERSE simultaneously provides a bridge program for the summer between undergraduate and graduate school, an enrichment experience for current University of Nebraska graduate students, and an opportunity for faculty in the early years of a professional academic position to receive significant mentoring with regard to both research and teaching.

We next list (alphabetically) some DMS-supported researchers who are remarkable both for the intrinsic merit of their research achievements and for their mentoring of undergraduate students, graduate students, and postdoctoral fellows.

Roberto Camassa, Gregory Forest, Richard McLaughlin, Michael Minion, and Richard Superfine (University of North Carolina, Chapel Hill), known for their work on fluid dynamics, are co-PIs of an RTG project that combines mathematics and experiments with a physical water tunnel (EMSW21-RTG-0502266).

Carlos Castillo-Chavez (Arizona State University) directs a research program at the interface of the natural and social sciences and puts emphasis on the role of dynamic social landscapes in disease evolution. He also directs the Mathematical and Theoretical Biology Institute (MTBI), which focuses on providing research opportunities at the interface of the biological, computational and mathematical sciences from the undergraduate to the graduate and postdoctoral levels. MTBI received an MCTP award (EMSW21-MCTP-0502349) to further its goal of providing a model for education through research in a collaborative setting.

In recent years, Richard Gardner (Western Washington University) has worked on geometric tomography (DMS-0203527 and DMS-0603307), an area that deals with retrieval of information about a geometric object from data about its projections on planes. This research has led to individual undergraduate research projects.

Carlos Kenig (University of Chicago) is a key player in the area of harmonic analysis and partial differential equations (DMS-0456583). In addition to his own impressive work, he has mentored a large, strong collection of graduate students, postdocs, and junior faculty, including a stellar group of junior and mid-career female researchers.

Nancy Kopell (Boston University) is co-director of the Center for BioDynamics (CBD), a model for how to build a vibrant interdisciplinary center. Her pioneering work in the modeling of neurons and neural networks has inspired a generation of mathematical biologists. She has mentored numerous undergraduates, graduate students and postdoctoral fellows, and recently received an RTG award (EMSW21-RTG-0602204).

Barry Mazur (Harvard University) is a leading researcher in number theory and arithmetic geometry (DMS-0403374, DMS-0514066) as well as an exceptional mentor. His influence can be measured by the number of his former students and postdocs who are now prominent figures in arithmetic geometry and supported by NSF. Mazur is, in addition, active in organizing workshop and conference.

Peter Sarnak (Princeton University), a remarkable mathematician with many research interests (DMS-0353870, DMS-0500191), has been an outstanding mentor for junior mathematicians. He has supervised, or is supervising, more than 40 graduate students, and his former students are well represented among the young analytic number theorists funded by DMS through individual investigator, CAREER, and FRG awards. Like Mazur, Sarnak is an active organizer of conferences and workshops.

B.2. Outcome Goal for Ideas: Enabling "discovery across the frontier of science and engineering, connected to learning, innovation, and service to society".

In geometry and topology, the past three years have seen dramatic advances in understanding of knot theory and low-dimensional topology. For example, it is now known that the Heegaard Floer knot invariants, discovered a few years ago by Peter Ozsvath (Columbia University; DMS-0505811) and Zoltán Szabó (Princeton University; DMS-0406155) are combinatorial in nature. The NSF is funding the leading experts in this area as well as much work related to Grigori Perelman's celebrated solution of the Poincaré conjecture. It is also gratifying to see that many NSF-supported projects in this program have significant and rather unexpected practical applications. We have chosen five examples, listed alphabetically by the name of the PI.

Gunnar Carlsson (Stanford University) has explored algebraic topology as a tool in feature location, feature classification, shape recognition and shape description (DMS-0354543). He is part of a multi-departmental group whose goal is to develop flexible topological methods as well as software tools for understanding high-dimensional data sets that are difficult to analyze with standard methods (for example, data sets that are highly curved or contain singularities).

The research of Charles Epstein (University of Pennsylvania) on contact geometry and complex analysis has applications to medical imaging, yielding a practical algorithm in nuclear magnetic resonance (DMS-0603973).

Robert Ghrist (University of Illinois, Urbana-Champaign) received one of the elite PECASE awards (Presidential Early Career Award for Scientists and Engineers) made to the most meritorious CAREER award recipients (DMS-0337713). He has applied techniques from algebraic topology to shape-planning of modular and self-assembling robots and to data reconstruction from large sensor networks. He also has a strong record of including mathematics and engineering undergraduates in his research activities. Ghrist's research recently led to an $8 million DARPA grant on "Sensor Topology and Minimalist Planning".

The focused research group (DMS-0354772) led by Zhenghan Wang (Indiana University) has explored a new paradigm for quantum computing based on topological quantum computing, a fault-tolerant model involving topological quantum field theories.

Jeffrey Weeks, an independent scholar, received NSF funding (DMS-0452612) for a project on "Cosmic Topology and Software Development". The associated research applies geometrical and topological knowledge to ongoing efforts to understand the shape and nature of the universe. These beautiful ideas are made accessible through software from an award-winning Web site (`www.geometrygames.org`) that can be enjoyed by middle school, high school and college students.

The three years covered by this COV were marked by a number of outstanding research achievements in the Algebra, Number Theory and Combinatorics program, as can be seen by the number of longstanding conjectures that were solved. We list some of the most striking advances.

In early 2005, Daniel Goldston (San Jose State University) together with his collaborators János Pintz and Cem Yildirim, made a major breakthrough in the study of prime numbers (DMS-0300563, an RUI grant): they showed that there are gaps between primes which are significantly smaller than the average gap. Their work is both a remarkable achievement and a step toward resolving one of the oldest and most famous conjectures in number theory, the twin prime conjecture, which asserts that there are infinitely many prime pairs p and $p + 2$.

Christopher Hacon (University of Utah) and James McKernan have proved the existence of flips in dimension four, and announced a proof of existence of minimal models in all dimensions (DMS-0456363). This is a longstanding and central problem in algebraic geometry. In 1990, Shigefumi Mori was awarded the Fields Medal for the three-dimensional case. This stunning result almost completes a program of research showing that algebraic varieties can be simplified to a state which can be decomposed into pieces with negative, zero, and positive curvature, and fiber spaces of these, somewhat in the same vein as the geometrization conjecture decomposes a three-manifold into pieces with a standard geometry.

Chandrasekhar Khare (University of Utah), in collaboration with Jean-Pierre Wintenberger, has announced a proof of the "level-one Serre conjecture" (DMS-0355528), a celebrated problem in number theory for twenty years.

The work of Andrei Okounkov (Princeton University) was recognized with a Fields Medal at the 2006 International Congress of Mathematicians "for his contributions bridging probability, representation theory and algebraic geometry". The implications of his work include connections between representation theory and randomness, and between real algebraic geometry and the melting of crystals (DMS-0441083).

During the summer of 2006, Richard Taylor (Harvard University) announced a proof of the Sato-Tate conjecture (DMS-0600716), building on his previous work with his collaborators Laurent Clozel, Michael Harris and Nicholas Shepherd-Barron. His approach uses a generalization of the Wiles/Taylor–Wiles method to show modularity of ℓ-adic Galois representations.

The Applied Mathematics and Mathematical Biology programs saw many impressive advances over the three-year period studied by the COV. Several of these achievements were widely reported in the popular press because of their practical or technological importance.

Samuel Kou (Harvard University) has developed new statistical models for understanding data on single-model trajectories in biochemical processes (DMS-0449204). This work is important for reconciling single-molecule and ensemble kinetics and new indicators of dynamic disorder in catalytic reactions.

Steven Strogatz (Cornell University; DMS-0412757) and Edward Ott (University of Maryland; DMS-0434225) explained why the Millennium Bridge in London began to wobble as soon as it was opened to pedestrians in 2000, leading to its immediate closure. Ott and Strogatz's analysis, featured in *Nature* and in the *New York Times*, uses novel mathematical ideas, introduced originally in the context of synchronization of fireflies, together with a description of the bridge's mechanical properties. (The bridge's design was subsequently modified, and it reopened in 2002.)

Jonathan Taylor (Stanford University) has applied ideas from geometry and topology to signal detection problems and assessment of significance in neuroimaging applications (DMS-0405970).

David Terman and Alice Yew (Ohio State University) have had tremendous impact in developing and analyzing computational models for electrical activity in parts of the basal ganglia system (DMS-0103822). Dysfunction in these areas is implicated in movement disorders such as Parkinson's disease and Huntington's disease. The work of Terman and Yew directly studies movement disorders, including developing and analyzing models to describe the impact of dopamine changes.

Supported by the DMS Analysis and Applied Mathematics programs, Craig Tracy (University of California, Davis; DMS-0304414, DMS-0553379) and Harold Widom (University of California, Santa Cruz; DMS-0243982, DMS-0552388) have made fundamental contributions to the theory of random matrices and their applications to theoretical physics and computer science. In particular, their work has led to a solution of Ulam's long-standing problem on increasing subsequences of random permutations.

A flurry of press coverage in 2006 about an "invisibility cloak" involved research by two groups of NSF-funded researchers.

Research in 2003 about the mathematics behind tumor detection by Allan Greenleaf (University of Rochester; (DMS-0138167 and DMS-0551894) and Gunther Uhlmann (University of Washington; DMS-0245414, DMS-0554571, and EAR-0417900), in collaboration with Matti Lassas (Helsinki) and Yaroslav Kurylev (UK), addressed the problem of cloaking objects (rendering them invisible) to arbitrary fields. This led them to describe a worst-case scenario in which a tumor would be undetectable. Their more recent work, published in 2006, has improved the mathematical analysis of methods that can render objects "invisible".

In 2006 Graeme Milton (University of Utah) and Nicolae Nicorovici showed that it is possible to obtain cloaking by relying on a "superlens" (DMS-0411035), building on recent advances in the mathematical analysis of effective properties of materials. This work, which promises new applications in diagnostic imaging and optical communications, was widely reported in the popular press and highlighted in a perspective article in *Science*.

Several groups of physicists have already used these mathematical results, and engineers are using them to build prototype cloaks. There is now a world-wide race to realize cloaking devices experimentally.

B.3. Outcome Goal for Tools: Providing "broadly accessible, state-of-the-art S&E facilities, tools and other infrastructure that enable discovery, learning and innovation.

The COV noted a number of examples where DMS support resulted in tools that have enabled discovery, learning, and innovation. These tools consist mainly of software that is distributed freely on the Internet. Some of these tools are widely used by a variety of researchers inside and outside the mathematical sciences.

Work on matrix computations in parallel computing environments by Alan Edelman (MIT; DMS-0314286) has evolved into a company, Interactive Supercomputing, whose software facilitates parallel numerical computation.

SLEDGE++ is a widely used discontinuous Galerkin finite element discretization package, written by Jan Hesthaven (Brown University; DMS-0132967), Tim Warburton (Rice University; DMS-0512673), and Lucas Wilcox (University of Texas, supported as a Ph.D. student at Brown by DMS funding).

CLAWPACK is a software package written by Randall LeVeque (University of Washington; DMS-0609661) designed to compute numerical solutions to hyperbolic partial differential equations using a wave propagation approach.

SAGE (Software for Algebra and Geometry Experimentation), funded by DMS-0555776, is free open source software that supports research and teaching in algebra, geometry, number theory, cryptography, numerical computation and related areas. A key feature is that SAGE brings together a number of specialized programs and enables their seamless use.

Research supported by DMS has led to new tools in other areas. For example, the work of Guillaume Bal (Columbia University; DMS-0554097) on inverse problems has contributed to a combination of optical tomography and optical molecular imaging which together promise a diagnostic tool to detect disease before actual phenotypical symptoms appear.

B.4. Outcome Goal for Organizational Excellence: Providing "an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices".

The COV regards DMS itself as an excellent example of an agile, innovative organization, for several reasons.

In terms of the regular research grants, the program officers are impressively nimble in sorting the proposals, building review panels, and finding and distributing funds. Panels are well organized and the program officers make effective use of panel members' expertise. When proposals fall outside the expertise of a panel, program officers succeed in finding appropriate mail reviewers.

Program management within DMS is characterized by a flexible team approach, illustrated by the "mega-program" structure and the year-end equalization process.

Program officers work tremendously hard in meeting the ever-growing interest in interdisciplinary work; indeed, this part of their job description is especially time-intensive and challenging. The DMS would better meet its mandate if it had four to six more program officers.

The new FRG and RTG programs have an imaginative format that has stimulated several interesting and often interdisciplinary programs.

DMS recognizes and rewards innovative approaches in the mathematical community. For example, DMS partially funds the ARCC (American Institute of Mathematics Research Conference Center; DMS-0111966). Workshops at this center have a unique, organic model for interactions between research mathematicians. In addition, ARCC is unusually scrupulous about seeking out researchers who are not at major research institutions and about promoting diversity.

Another innovative program partially supported by DMS is the Institute for Advanced Study/Park City Mathematics Institute (DMS-0437137 and DMS-0554309). In addition to its excellent publications, one of this institute's mandates is a three-week summer session whose topic changes yearly. Participants include secondary school teachers, faculty from undergraduate institutions, undergraduate and graduate students, and researchers in both mathematics and mathematics education. To quote one participant, "Go there and it changes your life".

PART C. Other Topics

C.1. Please comment on any program areas in need of improvement or gaps (if any) within program areas.

Group 1. We suggest that DMS consider instituting small one-time start-up awards, along the lines of the Research Initiation Grants and/or the First Award scheme of EPSRC (UK), to encourage promising young researchers to stay active in the field.
`www.epsrc.ac.uk/ResearchFunding/Opportunities/NewAcademics/FirstGrant/default.htm`

Group 2. Subcommittee 2 expressed some concern about the decrease in the Foundations Program budget. The number of proposals submitted to the program has been stable and the field is as vibrant as ever, with exciting connections to several areas of mathematics and computer science. It is hoped that DMS will be able to address this issue through both existing resources and the proposed Cyber-enabled Discovery and Innovation (CDI) initiative.

The subcommittee also thought that it might be possible to clarify and simplify the the process by which Major Research Instrumentation (MRI) and Scientific Computing Research Environments for the Mathematical Sciences (SCREMS) proposals are handled. In particular, sometimes the proposals seem to be handled by a single panel so it was not clear to us why two separate (fairly small) programs existed.

Group 3. Given the large size of the analysis program, Subcommittee 3 sees a need for more consistency in the evaluation of research proposals across different subfields of analysis.

Subcommittee 3 observed that the MCTP program solicitation is somewhat vague, and this appeared to lead to some confusion in the evaluation process.

C.2. Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

Group 1. The subcommittee noted with concern that the success rate for research grants with female PIs over the past 3 years is significantly lower than that with male PIs. Increasing the number of junior awardees might help to ameliorate this problem.

C.3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

Group 2. Subcommittee 2 explored ideas for increasing participation in proposal review panels. One suggestion that has perhaps been made before is to consider holding the panels in different places around the country. This might be feasible since all files seem to be available electronically.

C.4. Please provide comments on any other issues the COV feels are relevant.

Group 2. The subcommittee would like to encourage the NSF to continue to explore ways to increase the number of mathematics majors in US colleges and thereby the number and quality of students who go on to graduate school.

C.5. NSF would appreciate your comments on how to improve the COV review process, format and report template.

Group 2. The subcommittee discussed various ways to try to speed up the COV review process. One suggestion was that the chair and subcommittee chairs might meet (possibly by teleconference) prior to the COV meeting and assign jackets to the various committee members to read, much as proposals are assigned to panel members before a panel meeting. Even if the jackets were not accessible until the panel began, this could make the initial stages of the evaluation more efficient. It would also permit the chair to brief the subcommittee chairs on their responsibilities. Despite this, it was felt that three days would still be needed for a COV meeting.

Group 3. This COV included a few members who had served on a previous COV, and this is a good practice to ensure continuity and efficiency.

The current process is well managed, and our requests for additional information were addressed in a timely manner.

SIGNATURE BLOCK:

For the Committee of Visitors, Division of Mathematical Sciences

Margaret H. Wright

COV Chair

Appendix A. Members of the 2007 Committee of Visitors

1. Stephanie Alexander, University of Illinois at Urbana-Champaign
2. Rodrigo Bañuelos, Purdue University
3. Andrew Bernoff, Harvey Mudd College
4. Kaushik Bhattacharya, California Institute of Technology
5. Harold Boas, Texas A&M University
Chair, Subcommittee 3
6. James Carlson, Clay Mathematics Institute
7. Bennett Chow, University of California, San Diego
8. Chantal David, Concordia University (Canada)
9. Victor de la Peña, Columbia University
10. Patrick Eberlein, University of North Carolina at Chapel Hill
11. Erica Flapan, Pomona College
12. Sergey Fomin, University of Michigan
13. Wilfred Gangbo, Duke University
14. Eugene (Chuck) Gartland, Kent State University
15. Rhonda Hughes, Bryn Mawr College
Member, MPS Advisory Committee
16. Fern Hunt, National Institute of Standards and Technology
17. Iain Johnstone, Stanford University
Member, MPS Advisory Committee
18. Kirk Jordan, IBM
19. Diane Lambert, Google
20. Gregory Lawler, University of Chicago
21. Steven Lee, Lawrence Livermore National Laboratory
22. Dusa McDuff, State University of New York, Stony Brook
Member, MPS Advisory Committee
Chair, Subcommittee 1
23. Jorge Moré, Argonne National Laboratory
24. Mary Pugh, University of Toronto (Canada)

25. Arun Ram, University of Wisconsin, Madison
26. Andrew Ranicki, University of Edinburgh (United Kingdom)
27. Gail Ratcliff, East Carolina University
28. Paul Salamonowicz, National Geospatial Agency
29. Björn Sandstede, University of Surrey (United Kingdom)
30. Charles Steinhorn, Vassar College
31. Tatiana Toro, University of Washington
32. Clarence (Gene) Wayne, Boston University
    Chair, Subcommittee 2
33. Andrew Wiles, Princeton University
34. Margaret Wright, New York University
    COV Chair

Appendix B. Subcommittee definition and membership

Group	Disciplinary programs	I/I/I/W program
1	Computational Mathematics Topology Geometric Analysis	Institutes
2	Applied Mathematics Mathematical Biology Algebra, Number Theory, and Combinatorics Foundations	Infrastructure and Interdisciplinary
3	Analysis Probability Statistics	Workforce

Group 1
Alexander, Stephanie
Chow, Bennett
Eberlein, Patrick
Flapan, Erica
Gartland, Chuck
Jordan, Kirk
Lee, Steven
McDuff, Dusa (chair)
Moré, Jorge
Ranicki, Andrew
Salamonowicz, Paul

Group 2
Bernoff, Andrew
Bhattacharya, Kaushik
Carlson, James
David, Chantal
Fomin, Sergey
Hunt, Fern
Pugh, Mary
Ram, Arun
Sandstede, Björn
Steinhorn, Charles
Wayne, Gene (chair)
Wiles, Andrew

Group 3
Bañuelos, Rodrigo
Boas, Harold (chair)
de la Peña, Victor
Gangbo, Wilfred
Hughes, Rhonda
Johnstone, Iain
Lambert, Diane
Lawler, Gregory
Ratcliff, Gail
Toro, Tatiana

Appendix C. Conflict of Interest Report

The Division of Mathematical Sciences held its triennial Committee of Visitors (COV) on February 12–14, 2007. The COV was composed of 34 members from the scientific community chosen for their scientific expertise and awareness of developments in their respective fields of the mathematical sciences, as well as a sense of issues, perspective, and balance across the mathematical sciences. The 34 COV members composed a diverse committee with geographic, institutional, gender, ethnicity, age, private sector, and scientific representation. The following table describes the main features of the COV with respect to these issues:

Category	**Number**
Member of MPS Advisory Committee	3
Academic Institutional Type	
Research	19
Comprehensive	1
4-year	3
Public	11
Private	12
Industry	2
Private Foundation	1
Government Laboratory	3
Government Agency	1
Outside of US	4
Location	
Northeast	3
East	9
Southeast	3
Midwest	7
Southwest	1
West Coast	7
International	4
Female	11
Minority	6
No DMS Proposal in Past Five Years	10

The COV was briefed on issues of Conflict of Interest for the purpose of one of the COV's statutory responsibilities, namely the reading of proposals, reviews, and recommendations, and commenting on the handling of actions and the appropriateness of recommendations. Each COV member completed an NSF Conflicts of Interest form. Known conflicts, such as those involving the home institutions of COV members, were entered into the eCOV system prior to the start of the meeting. Other conflicts were entered as they became known over the course of the meeting. Entering these conflicts prevented COV members from electronically accessing proposals with which they were conflicted. None of the COV members was involved in the review of a program in which he or she had a pending proposal. The DMS COI officer was available at all times during the COV meeting to answer questions and resolve issues regarding conflicts of interest.

Agenda
Division of Mathematical Sciences Committee of Visitors
February 12 -14, 2007

Monday February 12
Stafford I Room 375

8:00 am	Continental Breakfast
8:30 am	Welcome and Charge to the Committee Dr. Tony Chan Assistant Director, Directorate for Mathematical and Physical Sciences
8:45 am	Welcome Dr. Margaret Wright Chair, DMS Committee of Visitors
9:00 am	Conflict of Interest Briefing Dr. Morris Aizenman Senior Science Associate, MPS
9:15 am	Overview of Division of Mathematical Sciences Dr. Peter March Division Director, DMS
10:00 am	Coffee break in Breakout Rooms Subcommittee 1 Room 310 Subcommittee 2 Room 380 Subcommittee 3 Room 390
10:20 am	Overview of Disciplinary Programs (in Breakout Rooms) Various Program Officers
10:40 am	How to Read an Award/Declination Jacket Various Program Officers
11:00 am	Begin Review of Disciplinary Programs
12:00 noon	Working Lunch
3:00 pm	Coffee Break
3:30 pm	Continue Program Review
6:00 pm	Reception Followed by Group Dinner

Tuesday February 13
Stafford I Room TBA

8:00 am	Continental Breakfast	
8:30 am	Committee of the Whole	
9:00 am	Move to Breakout Rooms	
	Subcommittee 1	Room 310
	Subcommittee 2	Room 380
	Subcommittee 3	Room 390
9:10 am	Overview of Institutes/Interdisciplinary/Workforce Programs (in Breakout Rooms) Various Program Officers	
9:30 am	Begin Review of Institutes/Interdisciplinary/Workforce Programs	
12:00 noon	Working Lunch	
1:30 pm	Discussion of Procedure and Timing (Committee of the Whole, Room 375)	
2:00 pm	Discussion and Drafting of Subcommittee Reports	
	Subcommittee 1	Room 310
	Subcommittee 2	Room 380
	Subcommittee 3	Room 390
6:00 pm	Working Dinner	

Wednesday February 14
Stafford I Room 375

8:00 am	Continental Breakfast
8:30 am	Presentation of Draft Reports By Subcommittee Chairs
9:15 am	Continue Discussion and Drafting of subcommittee Reports Subcommittee 1 Room 310 Subcommittee 2 Room 380 Subcommittee 3 Room 390
10:00 am	Continue Discussion of Subcommittee Reports and Overall Report (Committee of the Whole, Room 375)
10:30 am	Discussion of Report with DMS Staff
11:30 am	Briefing of Dr. Tony Chan, AD/MPS, by Committee of Visitors
12:30 pm	Working Lunch, Further Discussion with DMS Staff, Revisions to Report
3:00 pm	Adjourn