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Report to Congress on Interdisciplinary Research at the National Science Foundation

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Report to Congress on Interdisciplinary Research at the National Science Foundation

The America COMPETES Act directs the National Science Board (Board) to evaluate the role of the National Science Foundation (NSF) in supporting interdisciplinary research.[1] We are pleased to provide this assessment and highlight the wide array of mechanisms by which NSF supports interdisciplinary research.[2]

Although a precise definition of and measure for interdisciplinary research are much debated,[3] a recent report by the National Academies, *Facilitating Interdisciplinary Research*, put forward a broad description of interdisciplinary research that may be considered a working definition for this report: "Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice."[4]

Interdisciplinary Research at NSF

NSF plays an essential role in stimulating and strengthening U.S. competitiveness in global science and technology. It funds a wide array of superb scientific and engineering research, including much interdisciplinary research. Proposals for research support are by-and-large generated by the science and engineering community, and this "bottom-up" method of generating research proposals has been a significant advantage of the NSF system—and, more broadly, the U.S. system—of funding scientific research. It encourages the generation of cutting-edge proposals for research on the frontiers of knowledge and ensures their consideration by scientific peers on the basis of excellence. NSF does receive a large number of excellent proposals each year that are not funded because of budget limitations.[5,6] While much of the excellent research NSF is unable to fund falls within a single discipline, much also is interdisciplinary.

NSF's strong record of past and current support for interdisciplinary research is widely recognized. Indeed, the National Academies report referenced above states that NSF "...has been a leader and exemplar in supporting individuals, projects, and multi-institution programs for [interdisciplinary research]."[7] The Board finds that NSF is committed to offering wide-ranging opportunities to apply for interdisciplinary research funding, with support for such research embedded throughout programs and across each division and directorate, rather than being marginalized to a remote corner of NSF's activities or segregated in its own silo. With investigators in several different university departments and/or in several different universities, interdisciplinary proposals often cut across the NSF organizational structure.

The wide variety of mechanisms by which NSF supports interdisciplinary research is an advantage of NSF's system. Some NSF solicitations and programs are inherently interdisciplinary, while other programs accept or actively encourage interdisciplinary proposals even though the program is not inherently interdisciplinary. NSF also

welcomes proposals with interdisciplinary content that are not submitted in response to a targeted solicitation.[8] The science and engineering research community submits many proposals to NSF that are interdisciplinary in nature and reflect the natural development of contemporary science and engineering rather than an artificial "steering" of the research community by NSF. NSF's ability to review and fund proposals that originate in all these ways allows it to be responsive to new research ideas and directions from the community—including those that are interdisciplinary.

The America COMPETES Act has asked the Board for its recommendation for the proportion of NSF's research and related activities funding that should be allocated for interdisciplinary research.[1] In response, the Board urges NSF management to continue a high level of flexibility in the funding of interdisciplinary research, and recommends against designating a fixed portion of the NSF budget for funding such research, believing that it is not in the interest of scientific advances or of the Nation to do so. NSF should explore the most promising areas of science and engineering research as identified by the scientific and engineering research communities through maintaining wide-ranging opportunities for research funding and a rigorous, transparent evaluation of scientific merit and broader impacts. It is the nature of scientific progress that existing disciplinary fields and subfields develop and amalgamate to create new disciplines and cross-disciplinary fields. In this dynamic environment, NSF must constantly adapt its support for interdisciplinary research and, in fact, all varieties of scientific research, and should be unfettered in that effort.

Creating funding "silos" with arbitrary barriers and category labels, whether they be specifically disciplinary or interdisciplinary, runs the risk of creating an environment where science and engineering are confined and creativity becomes stifled—even with the best of intentions to ensure adequate support for worthy research proposals. Such an outcome would fail to advance the national interest to support transformational research.

Assessing the Extent of Interdisciplinary Research at NSF

Because interdisciplinary research permeates all of NSF and is funded using a variety of mechanisms, and, further, because what constitutes interdisciplinary research is much debated and often subjective, the amount of NSF-funded interdisciplinary research can only be estimated in a very broad sense. NSF proactively supports research in highly dynamic areas even while these areas are developing and defy easy classification. As new research areas emerge, NSF provides funding to push these frontier areas forward and, in doing so, promotes the creation of new disciplines. Some of these emerging areas are interdisciplinary in character, but there are no uniform guidelines for designating a research project as interdisciplinary, and proposals and awards are not designated as such in NSF databases. Likewise, defining criteria by which a research proposal would be designated as interdisciplinary would not be straightforward.[9] Nonetheless, there are some solid indicators of the extent of NSF support for research that is interdisciplinary in nature:

- The number of single investigator versus multiple investigator grants: In 2007, 46 percent of NSF awards had more than one principal investigator, compared with 18 percent in 1987 (see Appendix). There has been a marked trend toward the support of more multi-investigator awards in the past 2 decades.

- Co-funding or multi-directorate funding of awards: In 2007, 8 percent of NSF research awards received funding from more than one division and are, therefore, likely to be interdisciplinary.[10] The proportion of co-funded awards is certainly lower than the proportion of awards supporting interdisciplinary research as this does not include, for example, the many programs that explicitly call for interdisciplinary proposals but are funded out of a single division.

- The use of the term "interdisciplinary": Of the 342 active funding opportunities listed on the NSF website on July 10, 2008, 118 (35 percent) contained the term "interdisciplinary."[11] This indicator likely underestimates the actual amount of interdisciplinary funding opportunities, as programs may support interdisciplinary research even if that term does not appear in the program description.

While none of these indicators is a precise measure of NSF's support of interdisciplinary research, taken together they suggest that a significant amount of the research NSF funds is partially or entirely interdisciplinary. The substantial funding NSF awards to interdisciplinary research sends a clear signal to the research community that NSF is receptive to interdisciplinary research proposals and is actively engaged in supporting interdisciplinary research.

Merit Review Process for Interdisciplinary Research Proposals at NSF

Interdisciplinary research proposals are submitted to NSF through a number of avenues, including both solicited and unsolicited mechanisms.[8] When not invited by a targeted solicitation, investigators are encouraged to submit proposals with interdisciplinary content to the program that most closely aligns with their proposal and to identify other programs that would likely be interested in the proposal at the time of submission. Program officers employ a suite of review mechanisms to ensure fair consideration of interdisciplinary research proposals. The availability of multiple mechanisms for review provides flexibility to NSF program officers to choose the most effective method for evaluating interdisciplinary proposals. It also provides flexibility for investigators to submit interdisciplinary proposals through more than one avenue and have confidence that their proposals will be reviewed by experts with the backgrounds appropriate to fairly evaluate the proposal. Programs that are inherently interdisciplinary often use integrated review panels,[12] while unsolicited proposals with interdisciplinary content are often evaluated using co-review.[13] *Ad hoc* reviews are used to supplement both integrated panels and co-review mechanisms.[14] The flexibility provided by these review mechanisms is an advantage of the NSF merit review system and allows NSF to solicit, evaluate, and fund interdisciplinary research proposals that originate in a variety of ways.

In spite of the success of the NSF system of review to date, it is important to acknowledge that both generating and reviewing interdisciplinary proposals can be more difficult and complex than dealing with single discipline proposals. Therefore, NSF will need to remain vigilant in monitoring the quality of interdisciplinary proposal review. The Board is supportive of the aims of an NSF working group that is charged, in part, with recommending policies and best practices to facilitate both transformative and interdisciplinary research and looks forward to receiving their report when it is complete.[15] The Board notes that no solid information exists regarding the success rate of unsolicited proposals with interdisciplinary content and will encourage NSF management, in the process of its examination of interdisciplinary research support, to evaluate more quantitatively the review processes the Foundation uses for assessing and funding interdisciplinary proposals. As NSF management continues to monitor the success of efforts to support both disciplinary and interdisciplinary research and reports these efforts to the Board, we will continue to provide advice and recommendations on how NSF can best stimulate, welcome, and support interdisciplinary research in the future.

The Breadth of Interdisciplinary Research at NSF

NSF promotes interdisciplinary research through many mechanisms, including agency-wide cross-cutting programs such as Science and Technology Centers that build intellectual and physical infrastructures within and between disciplines.[16] Examples of current NSF programs with an explicitly interdisciplinary focus are the Cyber-Enabled Discovery and Innovation (CDI) initiative that promotes the use of computational thinking in science and engineering research and education;[17] Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences that provides jointly-conducted long-term research experiences for interdisciplinary balanced teams of undergraduates from departments in the biological and mathematical sciences;[18] the Cognitive Neuroscience program that seeks interdisciplinary proposals aimed at basic scientific understanding of a broad range of issues involving the brain, cognition, and behavior;[19] and the Dynamics of Coupled Natural and Human Systems program that supports basic research and related activities to enhance fundamental understanding of the complex interactions within and among natural and human systems.[20] The community has responded robustly to solicitations for interdisciplinary programs such as these, evidence that the research community is aware of and embracing interdisciplinary opportunities at NSF.[21]

The Major Research Instrumentation (MRI) program was identified as an area of special interest in the America COMPETES Act with respect to interdisciplinary research support. This program assists in the acquisition or development of major research instrumentation that is, in general, too costly for support through other NSF programs.[22] The MRI program encourages proposals that span the range of research instrumentation used by the science and engineering community. Although the MRI program is not targeted to support interdisciplinary research exclusively, it can do so, and the multi-user nature of the instrumentation acquired through the MRI program can spur new interdisciplinary collaborations.

Capacity Building for Interdisciplinary Research at NSF

A critical aim of NSF is to support the development of the Nation's future scientific and engineering workforce. Multiple NSF activities support this goal at both the undergraduate and graduate level, including the Research Experiences for Undergraduates (REU), Research in Undergraduate Institutions (RUI), and Integrative Graduate Education and Research Traineeship (IGERT) programs. In addition, many undergraduate and graduate students and postdoctoral scientists gain valuable interdisciplinary research experience through their involvement with interdisciplinary research projects or centers supported by regular NSF grants.

Both the REU and RUI programs receive and fund a significant number of interdisciplinary proposals. The REU program supports active research participation by undergraduate students in any of the research areas funded by NSF.[23] REU projects involve students in ongoing research programs (through REU Supplements) or in research projects specifically designed for the REU program (through REU Sites). The research experience of students funded through an REU supplement is likely to be interdisciplinary to the same extent as the ongoing research project with which they are associated. Of the 609 current, actively-funded REU sites, the title or abstract of 132 contain the term "interdisciplinary" (22 percent).[24] As noted above, this indicator of the extent of interdisciplinary research at REU sites probably underestimates the actual amount, as many projects are interdisciplinary even if that term does not appear in the project title or abstract. In June 2008, the Directorate for Biological Sciences sent a survey to its 135 currently-funded REU sites. The responses to the survey showed that 81 of the 124 sites (65%) that conducted an REU Site research program in summer 2008 identified more than one field of research undertaken by students at the site. This example from one NSF directorate suggests that the amount of interdisciplinary research being conducted by students at REU sites is likely quite large.[25]

The RUI activity supports research by faculty members of predominantly undergraduate institutions and in doing so provides undergraduates with research-rich learning environments.[26] All NSF directorates participate in the RUI activity, and each proposal is evaluated and funded by the NSF programs in the disciplinary areas of the proposed research. Many of the research projects do not fit neatly into a single NSF program, and NSF disciplinary programs often cooperate in the review of interdisciplinary research and shared-use equipment proposals. Of the 585 current, actively-funded RUI research awards, the title or abstract of 50 contain the term "interdisciplinary" (8.5 percent).[27]

Since 1997, one of the mechanisms through which NSF has supported graduate education has been the IGERT program. Unlike the REU and RUI programs, IGERT has an explicit goal to foster training in interdisciplinary research. Among the stated objectives of the IGERT program is to meet the challenges of educating U.S. Ph.D. scientists and engineers with interdisciplinary backgrounds who will pursue careers in research and education, and "to catalyze a cultural change in graduate education... by establishing new models for graduate education and training in a fertile environment for collaborative research that transcends traditional and disciplinary boundaries."[28] As an integral part of

the graduate training experience, the IGERT program supports research achievements based, in part, on cutting-edge interdisciplinary approaches.[29] The results of a recent study demonstrate that the IGERT program is fulfilling its interdisciplinary training objectives as evidenced by 83 percent of IGERT students reporting that they have developed the ability to communicate with and work on research problems with researchers from more than one discipline compared with 57 percent of non-IGERT students.[30]

Conclusion

Support of interdisciplinary research occurs throughout NSF and is an important aspect of NSF's contribution toward the Nation's scientific and engineering research productivity and infrastructure. The Board finds that the variety of mechanisms by which NSF solicits, evaluates, and supports interdisciplinary research and the training of those who participate in it, provides flexibility and vigor to NSF's efforts. Nonetheless, NSF is able to support only a portion of the excellent research proposed to it, and a substantial amount of the unfunded research is interdisciplinary.[6] The Board finds that a policy change that would designate a specific proportion of funding to be set aside for interdisciplinary research would have unintended negative consequences and negatively impact NSF's mission to support the best cutting-edge research in the Nation.

Endnotes

[1] Section 7007 of Public Law 110-69 (America COMPETES Act)

[2] The Board would like to acknowledge staff from the National Science Board Office who provided essential support for the preparation of this report, including Ms. Jean Pomeroy and Dr. Elizabeth Strickland. In addition, many National Science Foundation staff contributed to this report. Several deserve particular mention, including AAAS Science and Technology Fellow Dr. Patrick Clemins—who made substantial contributions to early drafts of this report—as well as Mr. Max Bronstein, Dr. Joan Frye, Dr. Clifford Gabriel, Dr. Judith Giordan, Dr. Corby Hovis, Dr. James Lightbourne, Dr. Kesh Narayanan, Dr. Sally O'Connor, Dr. Randy Phelps, AAAS Science and Technology Fellow Dr. Melanie Roberts, Mr. Vernon Ross, and Ms. Lisa-Joy Zgorski.

[3] The National Academy of Public Administration report *National Science Foundation: Governance and Management for the Future*, April 2004, discusses this issue extensively and, in particular, the inconsistency in the terminology for interdisciplinary research at NSF (pages 61-65). The difficulty in defining interdisciplinary research is something that has also been addressed in *Facilitating Interdisciplinary Research*, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005.

[4] *Facilitating Interdisciplinary Research*, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005, page 188

[5] During FY 2007, NSF received 44,577 proposals and made 11,463 awards for a funding rate of 26 percent. *Report to the National Science Board on the National Science Foundation's Merit Review Process: Fiscal Year 2007* (NSB-08-47), June 11, 2008, page 6. Available at: http://www.nsf.gov/nsb/, accessed June 24, 2008

[6] "A large number of potentially fundable proposals are declined each year... approximately $1.8 billion was requested for declined proposals that had received ratings at least as high as the average rating (4.2 out of 5.0) for all awarded proposals. Over the last ten years, NSF's capacity to fund these highly rated proposals has diminished. In FY 1997, the ratio of awards to highly rated declines was 5:1; in FY 2007, that ratio had dropped to less than 2:1. NSF is thus supporting a smaller proportion of potentially fundable proposals. These declined proposals represent a rich portfolio of unfunded opportunities, proposals that if funded may have produced substantial research and education benefits." *Report to the National Science Board on the National Science Foundation's Merit Review Process Fiscal Year 2007*, (NSB-08-47), June 11, 2008, page 30. Available at: http://www.nsf.gov/nsb/, accessed June 24, 2008

[7] *Facilitating Interdisciplinary Research*, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005, page 119

[8] In 2005, 80% of the research proposals processed at NSF were unsolicited (i.e., not in response to a solicitation with a targeted research focus). *Impact of Proposal and Award Management Mechanisms*, Final Report, August 1, 2007, NSF 07-45, Figure 18, page 31. Available at: http://www.nsf.gov/pubs/2007/nsf0745/index.jsp, accessed August 12, 2008

[9] For example, must interdisciplinary research require researchers from multiple disciplines or could a single investigator perform interdisciplinary research? Does interdisciplinary research require attacking an interdisciplinary problem, or does the use of a methodology from a second discipline to address a problem within one discipline constitute interdisciplinary research? If researchers from multiple disciplines are involved in different aspects of a research project, but don't necessarily collaborate, is that interdisciplinary? When are two disciplines far enough apart to be defined as interdisciplinary? If long-standing collaborations are formed between two disciplines to address a set of research topics, at what point does a field become its own discipline?

[10] The data include funding for both new awards as well as continuing increments and supplements for awards made in prior fiscal years. EPSCoR co-funding is excluded. Data were provided by Mr. Vernon Ross, NSF Office of Budget, Finance, and Award Management.

[11] http://www.nsf.gov/funding/, accessed July 10, 2008

[12] For an integrated review panel, the program officer, in addition to normal panel diversity considerations, chooses the panel so that the relevant disciplines are represented. In this way, the panel will likely include a number of reviewers who can expertly assess each proposal, regardless of the specific subject areas in the

proposal. Integrated review panels allow reviewers with complementary expertise to interact as proposals are evaluated.

[13] In a co-review, the proposal is sent to multiple panels, and each evaluates the proposal based on the panel's area of expertise. After recommendations are received from all panels, the cognizant program officers decide whether to fund the proposal and how much each program will contribute to the award. The decision to request a co-review is at the discretion of the program officer to whom the proposal is originally submitted, but can be initiated by a request from the principal investigator. Co-review is advantageous in that the proposals can be fully discussed by multiple panels. This both expands the range of experts who are able to provide input on the proposal and facilitates the decision to co-fund a proposal by more than one division or directorate.

[14] Program officers frequently use *ad hoc* reviews in conjunction with integrated review panels and co-review, because many times it is neither possible nor practical to construct a panel that has sufficient expertise in the fields of study represented by the proposals under consideration. *Ad hoc* reviews are solicited by program officers from members of the research community and are submitted electronically. The use of *ad hoc* reviews significantly and efficiently expands the expertise of the reviewers who provide input on a proposal.

[15] *Report to the National Science Board on the National Science Foundation's Merit Review Process Fiscal Year 2007*, (NSB-08-47), June 11, 2008, page 34, available at: http://www.nsf.gov/nsb/, accessed June 24, 2008

[16] Program Solicitation NSF 03-550, available at: http://www.nsf.gov/pubs/2003/nsf03550/nsf03550.htm, accessed June 10, 2008

[17] Program Solicitation NSF 07-603, available at: http://www.nsf.gov/pubs/2007/nsf07603/nsf07603.htm, accessed April 28, 2008

[18] Program Solicitation NSF 08-510, available at: http://www.nsf.gov/pubs/2008/nsf08510/nsf08510.htm, accessed April 28, 2008

[19] Program Solicitation NSF-07-557, available at: http://www.nsf.gov/pubs/2006/nsf06557/nsf06557.htm, accessed June 25, 2008

[20] Program Solicitation NSF 07-598, available at: http://www.nsf.gov/pubs/2007/nsf07598/nsf07598.htm, accessed May 27, 2008

[21] For example, to date 1649 pre-proposals have been submitted to the Cyber-Enabled Discovery and Innovation initiative (NSF e-Jacket database, accessed May 20, 2008).

[22] Program Solicitation NSF 08-503, available at: http://www.nsf.gov/pubs/2008/nsf08503/nsf08503.htm, accessed April 22, 2008

[23] Program Solicitation NSF 07-569, available at: http://www.nsf.gov/pubs/2007/nsf07569/nsf07569.htm, accessed April 21, 2008

[24] http://www.nsf.gov/awardsearch/, accessed May 16, 2008

[25] Data provided by Ms. Jessica Koski and Dr. Sally O'Connor, NSF Directorate for Biological Sciences.

[26] Program Announcement NSF 00-144, available at: http://www.nsf.gov/pubs/2000/nsf00144/nsf00144.htm, accessed April 21, 2008

[27] http://www.nsf.gov/awardsearch/, accessed May 16, 2008

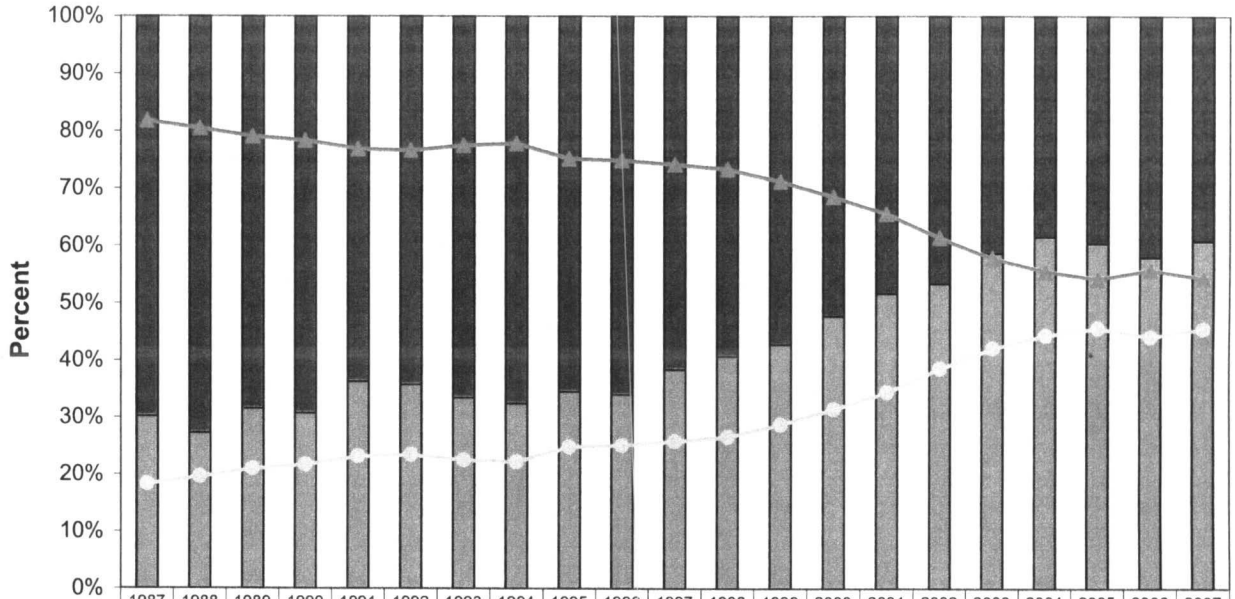
[28] Program Solicitation NSF 08-540, available at: http://www.nsf.gov/pubs/2008/nsf08540/nsf08540.htm, accessed April 21, 2008

[29] "The 136 IGERT projects submitting annual reports in 2006-2007 reported a total of 335 distinct research achievements. These achievements are defined as accomplishments of significant impact of the projects as pertains to the interdisciplinary research of each IGERT and cut across the Directorates of the NSF." These IGERT projects also reported 811 journal publications, 345 conference papers, 1,171 conference presentations, 52 book chapters, 14 books, 35 patents, and 61 patent applications. *IGERT 2006-2007 Annual Report*, NSF 08-40, page 7. Available at: http://www.nsf.gov/pubs/2008/nsf0840/index.jsp, accessed August 12, 2008

[30] *Evaluation of the Initial Impacts of the National Science Foundation's Integrative Graduate Education and Research Traineeship Program*, Final Report, Abt Associates, Inc., February 2006, NSF 06-17, page 22. Available at: http://www.nsf.gov/pubs/2006/nsf0617/index.jsp, accessed August 12, 2008

Appendix: Trend in Single vs. Multiple Investigator Awards at NSF

NSF Research Grants for Single Investigators (SIRPS) and Multiple Primary Investigators (PIs) by Percentage for both the Total Dollar Value [bars] and the Number of Grants [lines]



	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
By $ - SIRPs	70%	73%	68%	69%	64%	64%	67%	68%	65%	66%	62%	59%	57%	52%	48%	47%	41%	38%	40%	42%	39%
By $ - >= 2 PIs	30%	27%	32%	31%	36%	36%	33%	32%	35%	34%	38%	41%	43%	48%	52%	53%	59%	62%	60%	58%	61%
By # - SIRPs	82%	80%	79%	78%	77%	77%	78%	78%	75%	75%	74%	73%	71%	69%	66%	61%	58%	56%	54%	56%	54%
By # - >= 2 PIs	18%	20%	21%	22%	23%	23%	22%	22%	25%	25%	26%	27%	29%	31%	34%	39%	42%	44%	46%	44%	46%

SOURCE: Mr. Vernon Ross, NSF Office of Budget, Finance, and Award Management, April 2008