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Earth Science Instrumentation and Facilities Program Review

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The Instrumentation and Facilities (IF) program of the U.S. National Science Foundation's Division of Earth Sciences (NSF/EAR) supports a remarkably broad span of research, both in the science that is addressed and in the nature of awards provided, according to a review by a Committee of Visitors on 22–24 August 2007. The present article, written by committee members, provides a synopsis of our findings to promote community-wide discussion of the size, scope, and responsibilities of the IF program.

The IF program funds infrastructure ranging from an individual investigator's purchase of laboratory equipment to support for major, multiuser facilities requiring millions of dollars per year (Figure 1). Partial support is also provided for technicians (for up to 5 years, with a decreasing level of funding each year).

The quality, breadth, and quantity of IF-supported research are more advanced than ever, and the science is correspondingly diverse, including quantifying species recovery after the K–T mass extinction, based on insect damage evident in fossil leaves; documenting the continental lithosphere's dynamic response to the Yellowstone plume by spaceborne radar interferometry; measuring the rates of erosion and tectonic uplift in mountain belts by isotope geochemistry; and documenting current global climate change through seismicity beneath the Greenland ice sheet. The resulting impact of IF-supported research has been featured in major cross-disciplinary journals such as *Geophysical Research Letters*, *Nature*, and *Science*, and also in *Eos* and *Physics Today*.

Such Committee of Visitors' reviews, performed every 3 years as mandated for all NSF programs, provide an opportunity for the community to examine the integrity and efficiency of processes, and the quality of the results of investments, in the IF program. The present committee examined complete documentation (including reviews) for more than 120 funded and unfunded proposals of the approximately 700 proposals submitted in 2004–2006, and it found that the combination of external (mail) reviews, panel reviews (standing IF panel as well as "special emphasis" panels for reviewing major programs or facilities), and program officers' documentation amount to a responsive process characterized by multiple checks and balances. Both the research community and NSF can be proud of the standards being upheld, despite the problematic fact that many excellent research proposals are turned down due to lack of available funds.

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Big and Little Science: Evolution of the IF Program

The IF program has grown considerably over the past 20 years, with a large increase in support provided for major programs and facilities (facilities support, or FS; Figure 1). Small awards, for example, to individual investigators to acquire or upgrade equipment (equipment acquisition, or EA), have therefore decreased in proportion to the total IF budget. They have also decreased in real (inflation-adjusted) dollars. A key responsibility of the standing IF panel is to advise program officers on how to maintain a balance between the diverse program elements within IF, based on external reviews of proposals and other information. In fact, there has been a systematic but proportionately small transfer of funds from the facilities budgets to the smaller awards over recent years. That is, facilities support helped to

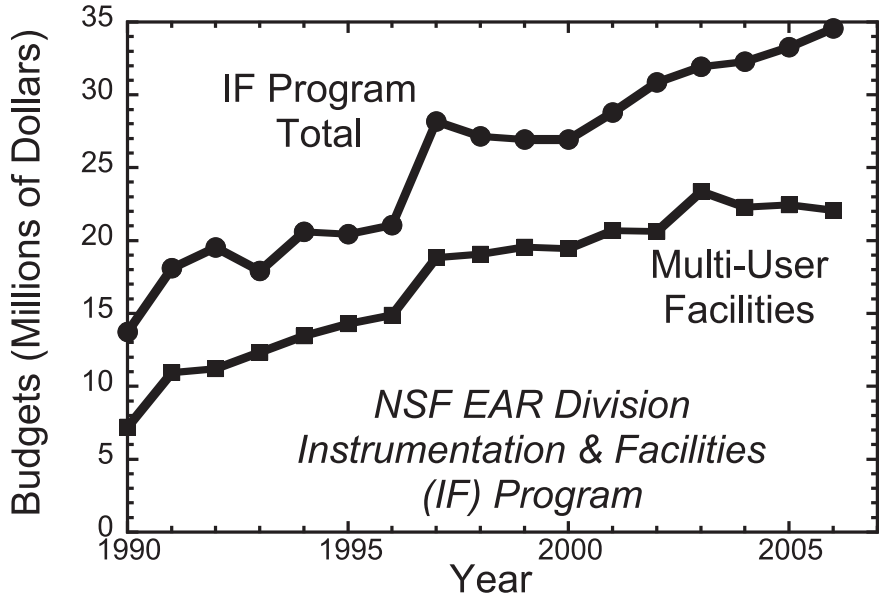

Fig. 1. Budget summary for the U.S. National Science Foundation's Division of Earth Sciences (NSF/EAR) Instrumentation and Facilities (IF) program through fiscal year 2006, showing the budget for multiuser facilities (facilities support, or FS) within IF as a function of time. The IF program also supports acquisition and upgrade of equipment (>$50,000) for individual investigators (equipment acquisition, or EA) at about $4–5 million per year; development of new instruments and analytic techniques (ITD) at about $1–2 million per year; support for technicians (TS) at under $2 million per year; and other funding (e.g., for early-career principal investigators) and geoinformatics (GI) at $4.5 million per year beginning in 2005. The largest facilities are Incorporated Research Institutions for Seismology (IRIS; about $12 million per year), as well as the UNAVCO, Consortium for Materials Properties Research in Earth Sciences (COMPRES), and GeoSoilEnviroCARS (GSECARS), each with about $1–2 million per year. Eleven additional awards make up the FS category. Dollars shown are nominal and have not been adjusted for inflation.

bring funds into IF, some of which have then been used to sustain equipment acquisition and other elements of IF. Checks and balances engage both the research community (through proposals, reviews, and service on panels) and NSF.

The success rate for IF proposals has recently plummeted, from 50–60% in 2004 and earlier to near 20% in 2006 and 2007. This change in success rates is correlated with a large increase in proposals and includes, among other factors, the effects of the U.S. Congress passing a continuing resolution (i.e., freezing budget levels) in fiscal year 2006.

Cost Sharing

In fall 2004, NSF removed requirements for institutions to share the costs of new capital equipment, a change that has had a considerable impact on equipment acquisition proposals. While cost sharing is still permitted, the National Science Board (NSB) decided to remove the requirement for several reasons, including difficulties in properly documenting and auditing cost sharing.

However, some reviewers continue to recognize cost sharing even when instructed not to consider it. Of course, value to the science per dollar awarded is a reasonable criterion in reviewing proposals, and it inevitably matters to a reviewer (and others) if an investigator requests all or, for example, only 50–70% of the amount needed to purchase a million-dollar instrument.

Although perhaps counterintuitive, not requiring cost sharing (combined with reviewers' reactions) seems to have benefited investigators at wealthy institutions that offer significant cost sharing. The field of play has apparently become less level, in this sense, and with cost sharing no longer supplementing as much of the program funds, success rates have dropped dramatically for equipment-acquisition proposals.

The committee therefore recommended that a requirement for cost sharing be reinstated, although with the added flexibility that support from other sources (e.g., from other NSF programs or other agencies) could take the place of institutional funds. A case can be made that more good proposals have been submitted when no cost sharing is required, because a barrier to entry into the IF competition has been removed. However, the resulting low success rates (≤20% of submitted proposals), the reduced total amount of money available for equipment purchase, and the advantage apparently enjoyed by institutions that could volunteer cost sharing point to the benefit of reinstating a uniform cost-sharing requirement. The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act, which U.S. President George W. Bush signed into law in August 2007, reauthorizes the NSF budget for 2008–2010, and it reinstates a 30% cost share for NSF Major Research Instrumentation program funding and requires that NSF reexamine the role of cost sharing in general, a task already being undertaken by the NSB.

What Reviewers Need to Know: Broader Impacts

NSF's review criterion of broader impacts appears to be a continuing source of confusion for the research community, with reviewers tending to apply too narrow a definition. Such broader impacts are not limited to precollege education or to enhancing diversity across the scientific community, for example, but also include activities to "enhance the infrastructure for research and education, such as facilities, instrumentation, networks and partnerships."

Almost every proposal made to IF thus matches the broader impact criterion by definition. To be sure, investigators and reviewers are typically in favor of additional, broader impacts of scientific research, but there is no benefit to artificially adding further broader impact features to an already well formulated proposal. And there is no need for reviewers to require further evidence of such impacts. A short statement clarifying NSF's intent, along with examples, is available at http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf.

Challenges in Managing Large Projects

Large programs and multiuser facilities support now account for more than 60% of the IF budget (Figure 1). The committee found an impressive array of science being pursued by diverse communities of outstanding researchers, yet the growth of these programs poses major challenges for their management, both within the research community and at NSF. In some cases, community governance structures appear inadequate. In particular, hallmarks of good management can be missing or poorly formulated, such as clearly defined goals and performance metrics; the alignment of responsibility and authority; long-term strategic planning; and effective succession plans, among others.

Because facilities support represents major investments, by both the research community and NSF, there is a need to focus attention on governance and management of the large programs and facilities. Typically, the research community–based governance structures emphasize excellence of science. This is appropriate, but management is also important in order to meet the objectives of the research community, NSF, and taxpayers. Management deficiencies can undermine the best motivated of projects.

Top-quality management and governance practices therefore need to be identified and communicated across the disparate communities of academic researchers involved with major programs, and existing community-based governance structures may need to be revised or replaced to ensure the effectiveness and sustainability of growing facilities support in delivering science. Continuing to address these issues in a timely manner is important for NSF's Division of Earth Sciences and for the Foundation more generally.

Conclusion

The Instrumentation and Facilities program of the NSF Division of Earth Sciences fosters exciting research with considerable societal impact, but the program faces budgetary pressures that over the long term could cripple its effectiveness. These pressures can be mitigated with continued due diligence in program balance and tight adherence to best practices. Most important, however, the scientific user community must communicate to fellow scientists, Congress, and the lay public about how world-class research infrastructure underpins fundamental scientific discovery, technological advances important for society, and the future, increasingly diverse community of researchers who will achieve these breakthroughs.

The full Committee of Visitors report is available at http://www.nsf.gov/geo/adgeo/advcomm/fy2007_cov/2007_EAR-IF_COV_Report.pdf.

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