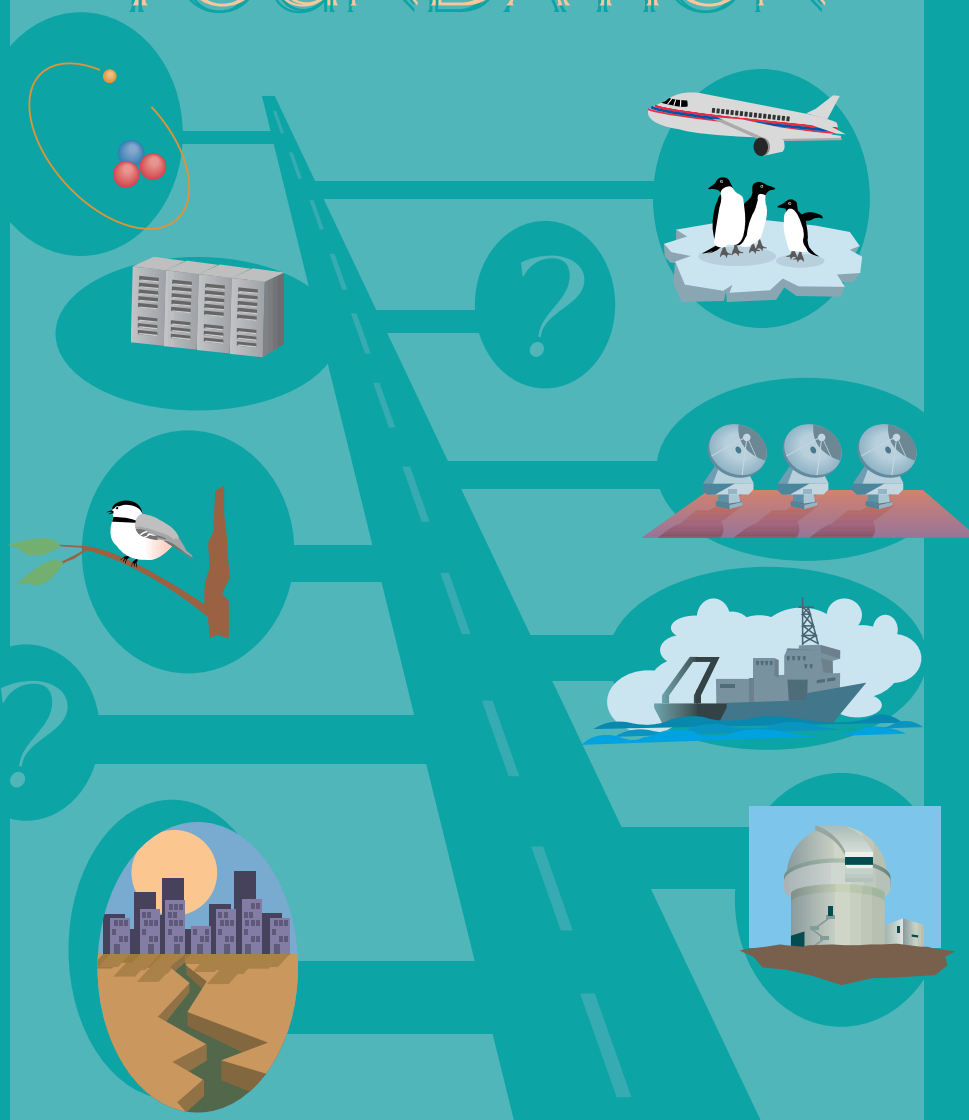


SETTING PRIORITIES

for LARGE RESEARCH FACILITY PROJECTS

supported by the

NATIONAL SCIENCE FOUNDATION



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Committee on Setting Priorities for NSF-Sponsored Large Research Facility Projects

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PREFACE

For many years, policy makers and the scientific community have focused attention on the support provided by the National Science Foundation (NSF) for large facilities used in scientific and engineering research. Previous reports have addressed the complex issues that arise in choosing among facility proposals and in balancing support for facilities and other tools with support for research conducted by individual investigators. As large facilities have become an increasingly prominent part of the nation's research and development portfolio and as NSF has entered a period of budgetary expansion, concerns once again have intensified.

In a letter to the president of the National Academy of Sciences dated June 12, 2002, Senators Barbara Mikulski, Christopher Bond, Ernest Hollings, John McCain, Edward Kennedy, and Judd Gregg stated that “questions remain as to whether the NSF has a satisfactory process for prioritizing multiple competing large-scale research facility projects.” The letter said that NSF funding of requests for large facility projects appears to be “ad hoc and subjective.” It also pointed out that the NSF inspector general had recently found “significant deficiencies in the Foundation's management and oversight of its large facility projects resulting in significant cost overruns not contemplated in their original budgets.” To address those concerns—which also have been expressed by members of the House Committee on Science and by the members and staffs of other congressional committees and subcommittees—the letter requested that the National Academy of Sciences “review the current prioritization process and report to us on how it can be improved.”

In response to the request, the National Academies appointed the Committee on Setting Priorities for NSF-Sponsored Large Research Facility Projects to address the following charge:

- ◆ Review NSF's current prioritization process as well as processes and procedures used by other relevant organizations.
- ◆ Develop the criteria that should be considered in developing priorities among competing large research facility proposals.
- ◆ Provide recommendations for optimizing and strengthening the process used by the NSF to set priorities among large research facility project proposals and to manage their incorporation into the President's budget.
- ◆ Provide recommendations for improving the construction and operation of NSF-funded large research facility projects.
- ◆ Provide recommendations regarding the role of the current and future availability of international and interagency research facility projects in the decision-making process for NSF funding of large research facility projects.

This report focuses on a portion of NSF's activities that is small (less than 4 percent) compared with the foundation's overall budget but is nevertheless central to its mission. It examines the policies and procedures governing awards made through the Major Research Equipment and Facilities Construction (MREFC) account. NSF uses the MREFC account to support the “acquisition, construction, commissioning, and upgrading of major research equipment, facilities, and other such capital assets” that cost more than several tens of millions of dollars. The report looks at how plans and proposals for large research facilities originate, how NSF chooses which facilities to support, and how it oversees their construction. These

“large research facility projects” represent major investments in the future of a given field of research. Funding the construction of a large facility affects the direction of research for many years and implies continued support for the operations and maintenance of the facility. Large research facilities also can have a substantial effect on regional economies, public perceptions of science, workforce training, and international cooperation in research. NSF's support of large facility projects is a critical element of US science and technology policy and warrants sustained attention from policy makers and the research community.

In responding to its charge, the committee examined numerous NSF documents, National Science Board (NSB) minutes and presentations, congressional testimony, and news articles, Web sites, and reports that discuss the facilities. The committee also compared NSF's current process with that used by the Department of Energy (DOE) Office of Science, the National Aeronautics and Space Administration (NASA) Office of Space Science, the United Kingdom, and Germany. In addition, it compiled examples of criteria that have been used or proposed for use to set research priorities by various organizations and several countries. This study also builds on the National Academies' Committee on Science, Engineering, and Public Policy's (COSEPUP's) 1994 report *Major Award Decisionmaking at NSF*, which addressed some of the same issues that are of concern here. Finally, the committee had useful discussions with the staff of the Senate Appropriations Committee, the House Science Committee, NSF, DOE, NASA, and disciplinary societies and researchers. Those people are listed in the acknowledgments section of the full report.

Given the ever-changing and draft nature of NSF's process for setting priorities among its proposals for large research facilities, the committee decided that it would not be fair to NSF to conduct an investigation of each decision it had made since 1995 (when the MREFC account was created) or even earlier (when some of the current projects began construction). The committee chose instead to examine the process as it exists today as outlined by NSF and to focus on how that process can be improved from the time of project conception to operation.

In doing so, the committee concluded that although NSF has improved its process for setting priorities among large facility projects, further strengthening is needed, if NSF is to meet the demands that will be made of it in the future. This report lays out specific recommendations that describe how large facility projects should be ranked within and among disciplines. In addition, it discusses how NSF can enhance preapproval planning and budgeting of projects and oversight of construction and operation once projects are approved to ensure that the nation's investment is ultimately successful. As research opportunities and agency initiatives change, the recommendations in this report should remain at the core of the procedures used to identify, develop, set priorities among, and manage large facility projects. By implementing the report's recommendations, NSF, in partnership with the research community, can develop a system of short-term and long-term planning that is sufficiently robust to direct funding to the most meritorious research projects. In that way, NSF can increase its already substantial contributions to the nation's science and engineering enterprise.

William F. Brinkman
Chair, Committee on Setting Priorities for NSF-Sponsored Large Research Facility Projects

EXECUTIVE SUMMARY

Large facilities play a more prominent role in science and engineering research today than they have played in the past. In FY 1995, the National Science Foundation (NSF) created the Major Research Equipment and Facilities Construction (MREFC) account to support the “acquisition, construction, commissioning, and upgrading of major research equipment, facilities, and other such capital assets” that cost more than several tens of millions of dollars.

Although such large facility projects represent less than 4 percent of the total NSF budget, they are highly visible because of their large per-project budget, their potential to shape the course of future research, the economic benefits they bring to particular regions, and the prominence of the facilities in an increasing number of research fields.

A number of concerns have been expressed by policy makers and researchers about the process used to rank large research facility projects for funding. First, the ability of new projects to be considered for approval at the National Science Board (NSB) level has stalled in the face of a backlog of approved but unfunded projects. Second, the rationale and criteria used to select projects and set priorities among projects for MREFC funding have not been clearly and publicly articulated. Third, there is a lack of funding for disciplines to conduct idea-generating and project-ranking activities and, once ideas have some level of approval, a lack of funding for conceptual development, planning, engineering, and design—information needed when judging whether a project is ready for funding in light of its ranking and for preparing a project for funding if it is selected. Those concerns have eroded confidence among policy makers and the research community that large research facility projects are being ranked on the basis of their potential returns to science, technology, and society.

To address the concerns regarding NSF’s process for identifying, approving, constructing, and managing large research facility projects, the committee makes the following recommendations:

1. The National Science Board should oversee a process whereby the National Science Foundation produces a roadmap for large research facility projects that it is considering for construction over the next 10-20 years.

Broad inputs from the scientific community must form the basis for the roadmap.

The roadmap should take into consideration the need for continued funding of existing projects and should provide a set of well-defined potential new project starts for the near term (0-10 years). These projects should be ranked against other projects expected to be funded in a given year and according to where they are positioned in time on the roadmap. Projects further out in time (10-20 years) will necessarily be less well defined and ranked qualitatively to yield a vision of the future rather than a precise funding agenda, as is the case for the earlier years.

Different categories of overlapping criteria, described briefly in the bullets below, need to be used as one moves from comparing projects within a field to comparing projects in a directorate or in the entire NSF. At each level, the criteria used in the previous level must continue to be considered.

- ◆ Within a field (as defined by NSF division) or interdisciplinary area: *scientific and technical criteria*, such as scientific breakthrough potential and technological readiness.
- ◆ Across a set of related fields: *agency strategic criteria*, such as balance across fields and opportunities to serve researchers in several disciplines.
- ◆ Across all fields: *national criteria* that assess relative need—such as which projects maintain US leadership in key scientific and engineering fields or enable the greatest numbers of researchers, educators, and students.

See box, *Criteria for Developing Large Facility Roadmaps and Budgets* for a more in-depth discussion of the proposed criteria.

A key constraint that must be imposed in the final stages of development is that the roadmap must reflect a reasonable projection of the large research facility budget over the next 2 decades. The roadmap is not a guarantee of funding but rather a plan for the development of NSF’s large research facility program.

Criteria for Developing Large Facility Roadmaps and Budgets

Overlapping categories of criteria should guide the preparation of the large facilities roadmap and NSF's annual budget submissions. Scientific and technical quality must be at the core of these criteria. Because these are large facility projects, they must have the potential to have a major impact on the science involved; otherwise, they should not reach the next step.

The rankings show what we would expect to happen first within a field, then within a directorate of NSF, and then across NSF. The criteria from earlier stages must continue to be used as the ranking proceeds from one stage to the next.

- **First Ranking: Scientific and Technical Criteria Assessed by Researchers in a Field or Interdisciplinary Area**
 - Which projects have the most scientific merit, potential, and opportunities within a field or interdisciplinary area?
 - Which projects are the most technologically ready?
 - Are the scientific credentials of the proposers of the highest rank?
 - Are the project-management capabilities of the proposal team of the highest quality?
- **Second Ranking: Agency Strategic Criteria Assessed Across Related Fields by Using the Advice of Directorate Advisory Committees**
 - Which projects will have the greatest impact on scientific advances in this set of related fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?
 - Which projects include opportunities to serve the needs of researchers from multiple disciplines or the ability to facilitate interdisciplinary research?
 - Which projects have major commitments from other agencies or countries that should be considered?
 - Which projects have the greatest potential for education and workforce development?
 - Which projects have the most readiness for further development and construction?
- **Third Ranking: National Criteria Assessed Across All Fields by the National Science Board**
 - Which projects are in new and emerging fields that have the most potential to be transformative? Which projects have the most potential to change how research is conducted or to expand fundamental science and engineering frontiers?
 - Which projects have the greatest potential for maintaining US leadership in key science and engineering fields?
 - Which projects produce the greatest benefits in numbers of researchers, educators, and students enabled?
 - Which projects most need to be undertaken in the near term? Which ones have the most current windows of opportunity, pressing needs, and international or interagency commitments that must be met?
 - Which projects will have the greatest impact on current national priorities and needs?
 - Which projects have the greatest degree of community support?
 - Which projects will have the greatest impact on scientific advances across fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?

Ranking projects across disciplines is inherently not an exact science; nevertheless, these criteria, as illustrated by the questions, provide a framework for a discussion of why one project is accorded a higher priority than another and a mechanism for the discussion to be as objective as possible in ranking projects across fields.

Within the ranking categories, the questions might change as governmentwide initiatives and unexpected occurrences shift priorities. Similarly some questions might have greater weight than others at certain times in the judgment of the NSB. The key element is for the questions and weighting to be identified before the ranking process begins and for a clear rationalization to be provided when proposed large research facility projects are ranked.

2. The National Science Foundation, with the approval of the National Science Board, should base its annual MREFC budget submission to Congress on the roadmap.

The annual budget submission should include the proposed yearly expenditures over the next 5 years for committed projects and for projects that will start in that period. It should supply a rank ordering of the proposed new starts and should include the rationale behind the proposed budget, the project ranking, and any differences between the budget submission and the roadmap.

The committee emphasizes that the final determination and approval of rankings across disciplines must be the responsibility of the NSF senior leadership subject to final approval by the NSB.

3. To ensure that a large research facility project selected for funding is executed properly, on schedule, and within its budget, the National Science Foundation should enhance project preapproval planning and budgeting to develop a clear understanding of the project's "technical definition" (also called "scope of work") and the "implementation plan" needed to carry out the work.

Once a project is funded, there should be provision for a disciplined periodic independent review of the project's progress relative to the original plan by a committee that includes internal and external engineering and construction experts and scientific experts and that will monitor the project's status and provide its evaluation to the NSB and NSF.

After the construction phase, a committee with a different external and internal membership that includes scientists and people with expertise in managing large facilities should monitor facility operations annually (or as needed).

Finally, NSF has created a new position—Deputy Director, Large Facility Projects in NSF's Office of Budget, Finance, and Award Management—to oversee the con-

struction of these projects. Given the new nature and importance of this position, it should be reviewed by a committee of internal and external experts to evaluate its operation and effectiveness within a 2-year period. A full description of this position is contained in the full report.

4. To ensure that potential international and interagency collaborations and ideas are discussed at the earliest possible stages, the Office of Science and Technology Policy in the Executive Office of the President should have a substantial early role in coordinating roadmaps across agencies and with other countries.

5. Given the congressional emphasis in the most recent National Science Foundation reauthorization bill and the importance of the MREFC account to the research community and the health of the US research enterprise, the NSF leadership and the NSB must give careful attention to the implementation of reforms in the MREFC account.

In its report, the committee has outlined a six-step process to implement these recommendations.

Large research facility projects will continue to constitute a vital component of NSF's science and technology portfolio by enabling researchers to examine previously inaccessible phenomena and answer previously intractable questions. NSF has strengthened the priority-setting process for these facilities in recent years, partly in response to reports from Congress and other organizations.

NSF now has an opportunity to strengthen the program further by incorporating the preparation of a roadmap into its planning process and by involving the research community more fully in the generation and ranking of ideas for large research facilities.

Making choices among competing proposals from different scientific fields will never be easy, but the recommendations and detailed steps described here can help NSF to excel in this critical part of its mission.

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