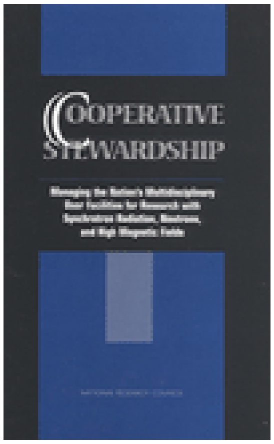

Cooperative Stewardship: Managing the Nation's Multidisciplinary User Facilities for Research with Synchrotron Radiation, Neutrons, and High Magnetic Fields

Committee on Developing a Federal Materials Facilities Strategy, National Research Council

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THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

COOPERATIVE STEWARDSHIP

Managing the Nation's Multidisciplinary User Facilities for Research with Synchrotron Radiation, Neutrons, and High Magnetic Fields

Committee on Developing a Federal Materials Facilities Strategy

Commission on Physical Sciences, Mathematics, and Applications

National Research Council

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Preface

The Committee on Developing a Federal Materials Facilities Strategy was appointed by the National Research Council (NRC) in response to a request by the federal agencies involved in funding and operating multidisciplinary user facilities for research with synchrotron radiation, neutrons, and high magnetic fields. Starting in August 1996, a series of conversations and meetings was held among NRC staff and officials from the National Science Foundation, the Department of Energy, the National Institute of Standards and Technology (Department of Commerce), and the National Institutes of Health. The agencies were concerned that facilities originally developed to support research in materials science were increasingly used by scientists from other fields—particularly the biological sciences—whose research was supported by agencies other than those responsible for the facilities. This trend, together with the introduction of several new, large user facilities in the last decade, led the agencies to seek advice on the possible need for interagency cooperation in the management of these federal research facilities.

The committee members (see Appendix A for biographical sketches), selected for their breadth of knowledge and experience in the conduct and management of research involving user facilities, as well as experience in managing large facilities and familiarity with the federal budget process, have conducted research at all of the federal user facilities discussed in this report and at many of the international ones. The committee was asked to explore possible strategies to address changing user demographics for synchrotron, neutron, and high-magnetic-field facilities owing to the changing nature of the science conducted and how this might affect the roles of federal agencies in supporting these facilities. (See Appendix B for the statement of task.)

The committee chose to focus its report on the issues of planning, operating, and funding facilities at the federal level and did not attempt to duplicate previous reports that have evaluated the state of the individual facilities or the research they support (BESAC, 1997, 1998). The committee did, however, study these reports as background for its work. The committee hopes that the federal agencies will be able to use this report to enhance the stability, efficiency, and effectiveness of existing and new user facilities.

The committee solicited input from the scientific community and heard stakeholders' concerns on the relevant issues. It also received a number of briefings (see Appendix C) from varied sources. The committee is grateful to the individuals who provided technical information and insight during these briefings. This information helped provide a sound foundation for the committee's work.

This study was conducted under the auspices of the NRC's Commission on Physical Sciences, Mathematics, and Applications and was administered by the staff of its Board on Chemical Sciences and Technology in cooperation with that of the Board on Physics and Astronomy. The chair is particularly grateful to the members of this committee, who worked diligently and effectively on a demanding schedule to produce this report.

Support for the study was provided by the interested agencies through the National Science Foundation.

John J. Wise, *Chair*
Committee on Developing a
Federal Materials Facilities Strategy

Acknowledgment of Reviewers

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Gabriel Aeppli, NEC Research Institute,
Frank Bates, University of Minnesota,
Boris Batterman, Cornell University,
Dean Eastman, University of Chicago,
Jack Fellows, University Corporation for Atmospheric Research,
Paul Gilman, Celera Genomics,
W. Carl Lineberger, University of Colorado,
Gilbert Marguth, Department of Commerce,
Manuel A. Navia, Althexis Company, Inc.,
Maxine Savitz, Allied-Signal Ceramic Corporation, and
Janet Smith, Purdue University.

Although the individuals listed above provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

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APPENDIXES

Executive Summary

The nation's six synchrotron light sources, five neutron sources, and high-field magnet laboratory are uniquely valuable resources that contribute to the development of new products and processes, create jobs, enhance the skill level of the U.S. scientific community, and increase U.S. competitiveness. Because of the high cost of building and operating these facilities,[1] only a limited number can be funded and they must be made widely available.

Each user facility consists of a core that generates the desired photons, neutrons, or magnetic fields and a surrounding array of experimental units that enable users to apply these commodities to research problems. These facilities, predominantly at universities and federal laboratories, are made available to national and international users for on-site experiments. Some 7,000 scientists use the facilities each year to conduct research supported by federal agencies, industry, private institutions, or the facilities themselves.

The current replacement value of the facility cores exceeds $5 billion. The annual operating costs for the facilities approach $300 million. Instrumenting and operating the experimental stations at the facilities require a significant additional

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[1] Government funding agencies initially referred to these facilities as "materials facilities" or "major materials research facilities" because many early users were from the materials science community. However, in recent years the user community has broadened enormously to include biologists, chemists, and environmental scientists. Not only have these more recent users made significant scientific and technological discoveries, but their successes are also fueling an unprecedented expansion of activities at these facilities. It is thus more appropriate to call these facilities "multidisciplinary user facilities" or just "user facilities," and the latter is the term used in this report.

investment that is shared by the facilities, other federal agencies, industry, and private institutions. The facilities represent a large and continuing investment of U.S. resources, and their ultimate owner—the public—expects maximum returns in terms of scientific and technological achievements. This investment has indeed paid off handsomely for the public for several decades.

Facility management and financing have evolved over the years, and most facilities are now managed with what might be termed the "steward-partner model." In this model, a single government agency (the steward) manages and funds a facility core, while the individual experimental units where research is conducted are managed and funded either by the steward or by other federal agencies, industry, or private institutions (the partners). When their missions and interests coincide, the steward and the users often receive support from similar sources and approach use of the facilities with similar backgrounds, experience, and expectations. This coincidence of interests and experience enables the steward-partner model to satisfactorily provide facility resources to the scientific community.

As discussed in Chapter 2, because of the growing number and diversity of users (Figure ES.1) and financial constraints, the missions, interests, and experience of the steward and users no longer coincide. In particular, at synchrotron facilities the number of users carrying out research in the life sciences has increased significantly. Because the life sciences are largely outside the traditional missions of the facility stewards, and because many of the new users require more facility and staff support than the traditional users, this growth has raised questions about the identity of the appropriate stewards and sources of facility funding. Financial constraints have also impeded funding for state-of-the-art instrumentation at the neutron facilities, so much so that some neutrons produced by the cores may not be optimally used (BESAC, 1993).

Conducted to explore strategies for addressing changing patterns of facilities use and their implications for facilities management to support scientific research, this study discusses several key issues:

- **Adequacy of funding.** In the last decade, growth in the numbers of both facilities and users has strained the budgets of funding agencies. While ad hoc methods have provided additional operating funds for the facilities, the funding agencies still struggle to upgrade and run the facilities while maintaining support for their traditional mission area research programs at efficient levels.
- **Stability of funding.** Currently a single steward has the responsibility for funding and maintaining each core facility. Because of the broadening of the user communities, there is pressure to expand the sources of core funding. However, history has demonstrated that if core operations and maintenance become dependent on dispersed funding, the entire facility operation may be threatened by the reduction or withdrawal of support by a single component.

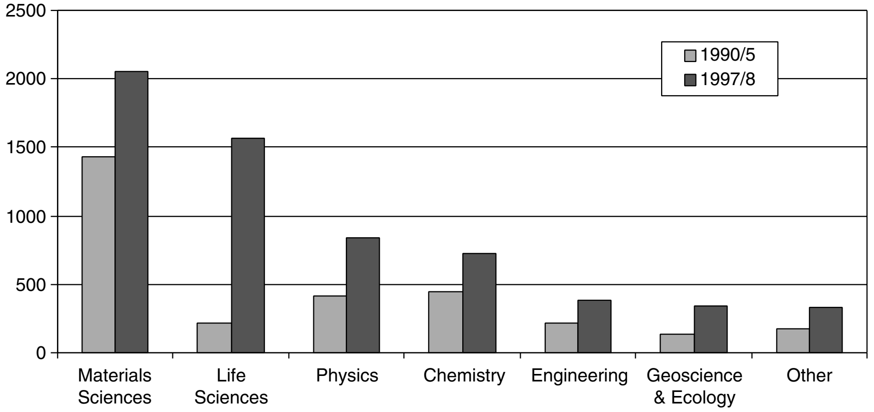

FIGURE ES.1 Growth in aggregate users at U.S. synchrotron, neutron, and high-magnetic-field facilities by field over time. Users at CHESS, SRC, and NIST CNR: 1990 and 1998; users at ALS, APS, NSLS, SSRL, HFIR, HFBR, IPNS, and LANSCE: 1990 and 1997; users at NHMFL: 1995 and 1998 (see Appendix E for an explanation of acronyms). SOURCE: Information supplied to the committee by Jack Rush, NIST CNR, on May 4, 1999; Sol M. Gruner, CHESS, on May 5, 1999; Janet Patten, NHMFL, on May 10, 1999; James W. Taylor, SRC, on May 17, 1999; and DOE Office of Basic Energy Sciences on June 10, 1999.

- **Adequacy of instrumentation.** Sufficient funding for the development, provision, maintenance, and upgrading of experimental instrumentation has seldom been available from the steward agencies. As a result, partnerships have been formed with outside groups to provide expertise and financing for experimental units at most of the synchrotron facilities. A lack of such partnerships at neutron facilities, combined with inadequate funding, has contributed in part to gross inadequacies in experimental instrumentation.
- **Changing user demographics.** The user communities of synchrotron, neutron, and high-magnetic-field facilities have increased significantly in recent years; the growth in the number of users from the biological community of synchrotron facilities is particularly notable. Many new users need more training and support from the facility than did their predecessors, and this further strains facility operating budgets. In addition, changes in the user demographics of a facility may lead to a mismatch between the mission of the primary funding agency and the scientific aims of the user community being served.
- **Legal concerns.** Facility users must sign agreements that are not transferable from one facility to another and that are considered by many to be unnecessarily complicated. In addition, the unresolved question of whether researchers

can retain full intellectual property rights to research conducted at the facilities is a concern to many users, especially at DOE facilities.

The committee examined recent trends in use and user demographics at each type of facility, as well as management models that have been used in the United States and in Europe. The committee concludes that the current steward-partner model should continue to provide the basic model for facilities management, but a permanent working group composed of stewards and partner agencies should be established to address issues that require the attention of all stakeholders. This enhanced management model is referred to as the cooperative stewardship model.

FINDINGS AND RECOMMENDATIONS

1. **Finding:** The synchrotron, neutron, and high-magnetic-field user facilities in the United States have contributed substantially to the advance of science and technology across a growing range of disciplines. But increases in the costs, management complexity, and diversity and number of users have created a need for a more coherent and better-articulated strategy for managing these facilities.

Recommendation: To ensure continued scientific and technological excellence and innovation at multidisciplinary user research facilities, U.S. funding agencies should adopt a cooperative stewardship model for managing the facilities. The elements of the cooperative stewardship model are the following:

- Responsibility for design, construction, operation, maintenance, and upgrading of each facility core should rest with a single clearly identified federal agency—the steward.
- The steward's budget should contain sufficient funds for design, construction, maintenance, operation, and upgrading of the facility core.
- The steward should engage the partners—other agencies, industry, and private institutions—in the planning, design, construction, support, and funding of the experimental stations and other subfacilities. The steward can also function as a partner in, for example, supporting experimental units or joining with others to form user groups.
- The steward should support a robust in-house basic scientific research program. This program should be of sufficient magnitude and diversity to ensure that the steward's mission is addressed and that external users have adequate quality and quantity of collaboration and technical support in their fields.
- The steward should support in-house scientific research to advance the science and technology required to produce high-quality photon and neutron beams and high magnetic fields.

2. **Finding:** As the size and disciplinary diversity of the scientific user community have increased, the programmatic heterogeneity and demands for funding have often grown beyond the scientific expertise and budgets of the steward agencies. Partners have provided assistance to the stewards, but only on an ad hoc basis.

Recommendation: A permanent interagency facilities working group, made up of representation from the appropriate steward and partner federal agencies, should be created under the auspices of the National Science and Technology Council of the Office of Science and Technology Policy to identify issues and to coordinate responses to needs that transcend the missions of the steward agencies. This group should be charged to:

- Review and coordinate support for the facility stewards' core operations and maintenance budget requests to the Office of Management and Budget (OMB) and Congress.
- Review and, if necessary, prioritize agency proposals to upgrade, create, or terminate facilities based on national needs and facility effectiveness.
- Monitor trends in the science, instrumentation, and user demographics at facilities and recommend changes in facility capabilities and funding levels and sources as needed.
- Periodically appraise facility performance in meeting the needs of the scientific user communities.
- Periodically investigate the need to shift stewardship of a facility either within or between agencies.
- Develop guidelines for agency cost sharing based on usage.
- Periodically examine user support and training levels to allow for changes in user demographics.

3. **Finding:** Each facility has implicit or explicit agreements with its users that address rights and responsibilities of both parties in such matters as safety, operations, logistics, proprietary research, and costs. These user agreements vary substantially in their complexity and requirements. Among facilities managed by the same steward—and even at the same site—there can be substantial differences that create difficulties for users and reduce the overall effectiveness of the facilities in promoting scientific excellence.

Recommendation: Steward agencies, facility management, and the facility user communities should reexamine and modify their user agreements to achieve maximum simplicity, uniformity, and portability.

4. **Finding:** Some users access the facilities as a relatively minor part of a more comprehensive research program intended to generate results of potential

commercial value. Current intellectual property policies, which appear to be a mix of agency-specific legal requirements and facility-generated practices, are complex and uneven across stewards and facilities and may not be appropriate for effective facility use. These factors can inhibit or needlessly complicate participation at the facilities.

Recommendation: The current intellectual property policies and practices at the facilities should be carefully assessed by an independent commission composed of representatives of steward and partner agencies; university, private company, and research institute partners; and user groups. The commission should recommend changes to optimize the protection of researcher and taxpayer interests and facilitate development of scientific findings.

1

Overview

The nation's six synchrotron light sources, five neutron sources, and high-field magnet lab are uniquely valuable resources that contribute to the development of new products and processes, create jobs, enhance the skill level of the U.S. scientific community, and increase U.S. competitiveness. Because of the high cost of building and operating these facilities,[1] only a limited number can be funded, and they must be made widely available. They have been located predominately at universities or federal laboratories and made available to users nationally and internationally to conduct experiments.

Each facility consists of a core that generates the desired photons, neutrons, or high magnetic fields, together with a surrounding array of experimental units that enable users to apply these commodities in their research. Typically, funding for construction and operation of the facility core comes from a single agency (the steward), while support for the experimental units and the visiting scientists can come from the steward or other government agencies or private sources (the partners). The facilities represent a large and continuing investment of the nation's

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[1] Government funding agencies initially referred to these facilities as "materials facilities" or "major materials research facilities" because many early users were from the materials science community. However, in recent years the user community has broadened enormously to include biologists, chemists, and environmental scientists. Not only have these more recent users made significant scientific and technological discoveries, but their successes are also fueling an unprecedented expansion of activities at these facilities. It is thus more appropriate to call these facilities "multidisciplinary user facilities" or just "user facilities," and the latter is the term used in this report.

resources, from which their ultimate owners—the public—expect maximum returns in terms of scientific and technological achievements.

These facilities have achieved phenomenal success (BESAC, 1997, 1998; NSF, 1988) and have contributed to the evolution of ever more advanced scientific capabilities. These capabilities in turn have attracted a larger and more diverse scientific user community. This same success and growth have created stresses in the system that threaten to make current management and funding methods untenable in the future. Several key issues are addressed in this study.

- **Adequacy of funding.** In the last decade, growth in the numbers of both facilities and users has strained the budgets of funding agencies. While ad hoc methods have provided additional operating funds for the facilities, the funding agencies still struggle to upgrade and run the facilities while maintaining support for their traditional mission area research programs at efficient levels.
- **Stability of funding.** Currently a single steward has the responsibility for funding and maintaining each core facility. Because of the broadening of the user communities, there is pressure to expand the sources of core funding. However, history has demonstrated that if core operations and maintenance become dependent on dispersed funding, the entire facility operation may be threatened by the reduction or withdrawal of support by a single component (see Chapter 3 section, "Dispersed Funding and Management Model").
- **Adequacy of instrumentation.** Sufficient funding for the development, provision, maintenance, and upgrading of experimental instrumentation has seldom been available from the steward agencies. As a result, partnerships have been formed with outside groups to provide expertise and financing for experimental units at most of the synchrotron facilities. A lack of such partnerships at neutron facilities, combined with inadequate funding, has contributed in part to gross inadequacies in experimental instrumentation.
- **Changing user demographics.** The user communities of synchrotron, neutron, and high-magnetic-field facilities have increased significantly in recent years; the growth in the number of users from the biological community of synchrotron facilities is particularly notable. Many new users need more training and support from the facility than did their predecessors, and this further strains facility operating budgets. In addition, changes in the user demographics of a facility may lead to a mismatch between the mission of the primary funding agency and the scientific aims of the user community being served.
- **Legal concerns.** Facility users must sign agreements that are not transferable from one facility to another and that are considered by many to be unnecessarily complicated. In addition, the unresolved question of whether researchers can retain full intellectual property rights to research conducted at the facilities is a concern to many users, especially at DOE facilities.

This study was initiated to explore strategies that steward and partner agencies can use to address these challenges.[2]

TYPES OF MAJOR USER FACILITIES COVERED IN THIS STUDY

Synchrotron Radiation Facilities

Synchrotron radiation is created when charged particles, traveling at relativistic speeds, are deflected by a magnetic field. This radiation is unique by virtue of its high intensity, brightness, stability, and broad energy range, extending from the far infrared to the x-ray region. The radiation is continuous in wavelength and is polarized and pulsed, with the exact characteristics depending on the generating device.

Historically, synchrotron facilities descended from particle accelerators that were developed for high-energy physics research. Gradually, other researchers, initially in materials science, realized that the photons produced by the particle accelerators could provide unique probes of the structure and properties of condensed-phase matter. Accordingly, "parasitic" instruments were attached to many of the accelerators to use these photons for research.[3] These parasitic research activities were so successful that a second generation of accelerators and storage rings was dedicated to the production of synchrotron radiation for research (Clery, 1997). The most important of these facilities have come on line since 1980, and, unlike the neutron sources discussed below, most have operated as user facilities from the outset.[4] The U.S. synchrotron user facility inventory includes five dedicated user facilities and one parasitic facility.[5]

Neutron Source Facilities

Neutron beams can be generated either by nuclear reactors (continuous beams) or by accelerator-based devices called spallation sources (pulsed beams). Like synchrotron light sources, spallation neutron sources depend on the particle accelerator technology developed initially by the high-energy physics community. A spallation neutron source consists of an accelerator that shoots packets of

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[2] The formal charge to the committee can be found in Appendix B.

[3] "Parasitic" use entailed use of a byproduct of a facility that is operated for other purposes.

[4] Presentation to committee by Martin Blume, American Physical Society, September 14, 1998.

[5] DOE is the steward of four synchrotron facilities (NSLS, SSRL, ALS, and APS) and NSF is the steward for two (SRC and CHESS). CHESS, at Cornell University, is parasitic to CESR, the Cornell Electron-positron Storage Ring. Other synchrotrons in the United States, such as SURF at NIST, CAMD at Louisiana State University, and the Duke University FEL, are not included in the scope of this study, as they do not currently serve significant scientific user communities outside their home institution. For definitions of acronyms, see Appendix E.

high-energy protons at heavy metal targets. The burst of neutrons that each proton-metal collision produces can be moderated so that its energy range is appropriate for condensed-phase matter research and then formed into a useful beam.

Historically, neutron facilities descended from neutron reactors that were first constructed in the early 1940s as part of the U.S. atomic energy program. These reactors were used initially to demonstrate the feasibility of chain reactions and to generate fissile materials for military purposes. Subsequently, several small reactors were built to produce radioisotopes by neutron activation, to study engineering issues related to the production of atomic energy, and, almost as an afterthought, to produce beams of low-energy neutrons for other research purposes. Pioneering experiments using neutrons, initially in materials science, demonstrated the value of neutron beams as probes of the properties of matter. The reactors built subsequently, in the 1960s, had neutron beam research as an important activity from the outset, although they did not open their doors fully to the outside community as user facilities until the 1970s. The U.S. facility inventory includes three reactor-based neutron sources and two spallation sources.[6]

High-Magnetic-Field Facilities

Magnetic field research has always been conducted at dedicated facilities because the importance of the responses of matter to magnetic fields has been obvious for more than two centuries. Magnetic field strength is a thermodynamic variable—similar to temperature and pressure—that affects the properties of matter; the stronger the fields, the greater the effect. High-magnetic-field facilities enable researchers to examine the response of matter to very strong magnetic fields. At present, magnets that generate fields greater than about 15 T are so costly to build and operate that they require significant federal support; lower field magnets, below about 15 T, do not need to be located in major facilities and thus are outside the scope of this study.

A high-magnetic-field laboratory, the Francis Bitter Laboratory, was established at the Massachusetts Institute of Technology in 1960 with the support of the U.S. Air Force. Its mission was to design, construct, and operate both superconducting and resistive electromagnets that generate high magnetic fields for research. In 1973 responsibility for management and funding of this facility was transferred to NSF. In 1990, following an open competition, the NSF established the National High Magnetic Field Laboratory (NHMFL) in Florida at a new facility built and operated by a consortium made up of Florida State University (Tallahassee), the University of Florida (Gainesville), and the Los Alamos National Laboratory. The NHMFL also has a pulsed facility located in New Mexico at the Los Alamos National Laboratory.

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[6] DOE is the steward for two reactor sources (HFBR and HFIR) and DOC-NIST is the steward for one (CNR). DOE is also the steward for the two spallation sources (IPNS and LANSCE).

USERS OF THE FACILITIES

The typical facility user is a member of a small research group based in an academic institution, a national laboratory, a for-profit corporation, the facility itself, or a similar foreign institution that is supported by individual investigator grants from agencies like NSF, NIH, and DOE, or by corporate funds. The user generally visits the facility a few times a year to collect data that cannot be obtained using ordinary laboratory equipment. The users have varying levels of experience with the technologies at these facilities. Some have been involved in instrument development and need little training or educational support. Others have only a modest understanding of the instrumentation and require extensive support from the facility. The number of inexperienced users is growing, and the implications of this trend are discussed in Chapter 2.

The user facilities attract talented scientists from around the world; each year some 10% to 20% of users of U.S. facilities are from foreign countries.[7] In turn, significant numbers of U.S. scientists travel abroad to use foreign facilities,[8] some of which provide capabilities that are either not available at U.S. facilities or are oversubscribed. This reciprocity of access to user facilities is essential for keeping both the instrumentation and U.S. scientific inquiry vital and state of the art.

MAGNITUDE OF THE USER FACILITY ENTERPRISE

The user facility enterprise is large, whether measured by the numbers of scientists involved, the cost of the facilities, or the size of the annual operating budgets. In 1998, about 7,000 scientists (see Table 1.1) used the major facilities in the United States, and when those who collaborate with users are included, the size of the community swells to several times that. The number of users is increasing due to recognition of the benefits that facility use offers to increasing numbers of scientific fields and to recent additions of new advanced capabilities at the facilities (see Chapter 2).

The magnitude of the U.S. investment in the neutron, photon, and high-magnetic-field sources of the major user facilities, the sources of funding of the facilities, and the ongoing operating and maintenance expenses are presented in Table 1.2. As the table shows, replacing the core portion of the existing user facilities would cost over $5 billion. The annual operating costs of the cores of

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[7] Data provided to the committee by the Office of Basic Energy Sciences, Department of Energy, on November 5, 1998; Sol Gruner, CHESS, May 5, 1999; and James Taylor, SRC, May 17, 1999.

[8] For example, U.S. scientists accounted for roughly 5% of the researchers at the Institut Laue Langevin (ILL) from 1995 to 1998, and the collaborations to which they contributed used roughly 15% of the beam time. Presentation to the committee from Alan Leadbetter, ILL, November 16, 1998.

TABLE 1.1 Numbers of Users at U.S. Multidisciplinary User Facilities in 1998

Type of Facility	Users in 1998	
DOE-operated synchrotrons	4,536	(NSLS, APS, ALS, SSRL)
NSF-operated synchrotrons	817	(CHESS, SRC)
DOE-operated neutron sources	371[a]	(IPNS, HFIR, HFBR, LANSCE)
NIST-operated neutron source	850	(CNR)
National High Magnetic Field Laboratory	293	
TOTAL	6,867	

NOTE: The term "users" counts on-site researchers who conduct experiments at facilities. An individual is counted as one user (per facility annually) regardless of number of visits in a year.

[a] In 1997 there were 810 users of DOE neutron sources. The decrease from 1997 reflects temporary, upgrade-associated shutdowns at LANSCE and HFIR, the shutdown of HFBR, and a change in the definition of a "user" at HFIR.

SOURCE: Information supplied to the committee by Jack Rush, NIST CNR, on May 4, 1999; Sol M. Gruner, CHESS, on May 5, 1999; Janet Patten, NHMFL, on May 10, 1999; James W. Taylor, SRC, on May 17, 1999; and DOE Office of Basic Energy Sciences, on June 10, 1999.

these facilities are almost $300 million. Table 1.2 does not include the magnitude of the investment in or the operating and maintenance costs of the instruments installed at the facilities.

FUNDING SOURCES FOR THE USER FACILITIES

The funds that support user facilities can be divided into funding for the cores and funding for the experimental units. The federal government has been and remains the source of most of the core funds, but state governments have made significant contributions to NHMFL and SRC, among others. Funding for the experimental units comes from remarkably heterogeneous sources.

Core Facility Funding

Because of its historical responsibility for atomic energy, the Department of Energy supports most of the nation's synchrotron light sources and neutron sources. DOE responsibility for most of the facilities has been assigned to the Office of Basic Energy Sciences; responsibility for LANSCE is shared between DOE's defense program and basic energy sciences. Other user facilities are supported by the Department of Commerce and NSF. The Department of Commerce sponsors a reactor-based neutron user facility and a small synchrotron at NIST.[9] NSF sponsors two synchrotron light sources and the National High Magnetic Field Laboratory.

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[9] The NIST synchrotron is not a multidisciplinary user facility and thus is not considered further in this report.

TABLE 1.2 Financial Information for U.S. Multidisciplinary User Facilities for 1998 (in 1998 dollars)

Facility	Funding Agency	Estimated Replacement Cost ($ millions)	Annual Operations ($ millions)
Synchrotron			
ALS	DOE	236	30.7
APS	DOE	1,242	82.4
CHESS	NSF	192	3.9[a,b]
NSLS	DOE	86	31.0
SSRL	DOE	210	21.7
SRC	NSF	35	4.0[b]
Neutron			
HFIR	DOE	800	33.8
HFBR	DOE	750	23.0
IPNS	DOE	160	11.2
LANSCE	DOE	1,000	6.6[c]
NIST CNR	DOC	500	7.2
Magnet			
NHMFL	NSF	142	24.2[d]
TOTAL		5,353	279.7

[a] Does not include costs to operate CESR, which supplies synchrotron radiation for CHESS at an annual operating budget of $8.6 million.

[b] Includes state and/or institutional cost sharing.

[c] LANSCE operations are listed for the Lujan Neutron Scattering Center only. The replacement cost is listed for the LANSCE facility, which includes nonscattering activities.

[d] Includes state and/or institutional cost sharing of $13.5 million.

SOURCE: Replacement costs information provided by the facilities. DOE facility operation costs data provided by DOE-BES, June 11, 1999. Operating costs for CHESS provided by Donald Bilderback, CHESS, March 4, 1999; for SRC by James Taylor, SRC, March 29, 1999; for NHMFL by James Ferner, March 4, 1999; and for NIST CNR by J. Michael Rowe, January 8, 1999.

Experimental Unit Funding

At neutron and photon facilities, a diverse group supports the research instrumentation and support staff of the experimental units. On the research floor of a single facility, there could be hardware purchased by several divisions of both DOE and NSF, by several NIH institutes and divisions, by nonprofit organizations such as the Howard Hughes Medical Institute, and by for-profit corporations. The widely varied user research projects are similarly supported by diverse sources.

The funding system for experimental instrumentation depends on the facility type. In synchrotron facilities funding is in large measure the result of decisions taken in the 1980s, when DOE constructed three new synchrotron light sources

(ALS, NSLS, and SSRL). To be able to use these new facilities more rapidly than could be internally supported, outside scientists organized into participating research teams (PRTs)[10] were invited to develop some of the instrumentation. PRTs served two purposes: (1) they provided a mechanism for recruiting the talent needed to design and construct the instrumentation required to bring the facilities online quickly and (2) they provided a mechanism for raising funds to build and operate that instrumentation. In exchange for their contributions to the facilities, the PRTs were granted 75% of the available time on their beamlines.

The PRT system has not been used for neutron facilities until recently; instrumentation has been provided by the facility. Limitations in facilities' budgets have impeded the development and construction of instrumentation necessary to optimize the neutron sources. However, neutron facilities now appear to be moving toward a system similar to that in place in the synchrotron light sources: for example, the current upgrade at LANSCE will involve instrument construction through spectrometer development teams.

The National High Magnetic Field Laboratory funding for instrumentation is predominantly provided by NSF and the state of Florida. DOE funded the preexisting pulsed field facilities at the Los Alamos National Laboratory of the NHMFL.

ORGANIZATION OF THIS REPORT

Chapter 2 provides a detailed discussion of the U.S. synchrotron, neutron, and high-magnetic-field user facilities, emphasizing trends in their scientific applications and user communities. The stresses faced by the facilities and their supporting agencies due to the changing needs of the user community and the management changes that may be required to meet these needs in the future are also discussed.

Chapter 3 traces the evolution of user facility management models in the United States, describes the current status of facility operation and funding, and compares them with models in user facilities in other countries. The strengths and weaknesses of the current stewardship models, either simple stewardship or steward-partner, are also discussed.

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[10] At various institutions these groups may go by other names, such as collaborative access team (CAT), instrument development team (IDT), or spectrometer development team (SDT), but their purpose and function are similar.

2

Major User Facilities

This chapter reviews the current status of the major U.S. user facilities (synchrotron light sources, neutron sources, and high-magnetic-field laboratory), the scientific and technical trends in each area, demographic trends in the user communities, and the implication of these trends for the management of the facilities.

SYNCHROTRON FACILITIES

Snapshot of Current Facilities and Planned Upgrades

Synchrotron light sources are characterized as first, second, or third generation, reflecting their evolutionary history. A first-generation source is one that is "parasitic"; that is, photons are generated as by-products of a storage ring operated for another purpose, usually particle physics. A second-generation source is dedicated to the production of photons. A third-generation source is optimized for high brilliance by the use of insertion devices called undulators and wigglers, which improve the intensity, focus, brilliance, or spectral bandwidth of the photon beam. A source can be reclassified either by a change in management policy, as occurred at the Stanford Synchrotron Radiation Laboratory (SSRL) when the focus for its core operation was redirected from high-energy physics research to photon production, or by upgrading the facility, as will soon take place at SSRL. Some types of research can be conducted on all generations of sources, and some require the properties of the more advanced sources.

There are currently six major synchrotron user facilities in operation in the United States (Appendix D). DOE supports two third-generation facilities (the

ALS at Lawrence Berkeley National Laboratory and the APS at Argonne National Laboratory) and two second-generation facilities (the NSLS at Brookhaven National Laboratory and the SSRL in Palo Alto, California). The NSF supports one first-generation facility (CHESS), which is parasitic on the high-energy physics program at Cornell University, and one second-generation facility, the SRC at the University of Wisconsin. In addition, the state of Louisiana supports the Center for Advanced Microstructure and Design (CAMD) at Louisiana State University, a second-generation facility not originally operated as a national user facility but now being developed into one. DOC supports the small synchrotron at the NIST campus in Gaithersburg, Maryland, a second-generation source that is used primarily by the NIST staff for calibrations. Because the last two are not now user facilities, they were not included in this study.

No additional U.S. synchrotron sources are planned to be constructed in the near future, although research is continuing on a fourth-generation concept that will likely be based on a free-electron laser (BESAC, 1999). Planned investments focus on upgrading current sources (e.g., SSRL) and developing new beamlines and experimental instrumentation at existing facilities.

There are currently around 35 synchrotron user facilities in operation in 13 other countries. These include two third-generation sources comparable to APS in France and Japan and four third-generation sources comparable to ALS in Italy, South Korea, Sweden, and Taiwan. As of 1997, 11 light sources were under construction outside the United States, including third-generation sources in Germany, Japan, and Switzerland; another 15 were in various stages of design, including a third-generation source in Canada that has been approved for funding and two in China and France that are expected to be funded.[1] The most advanced U.S. synchrotron facilities are regarded as state of the art and compare favorably with those in any other country.

Trends in the Scientific Applications of Synchrotron Sources

Scientific trends in synchrotron applications have been analyzed extensively in several recent reviews (BESAC, 1997; Structural Biology Synchrotron Users Organization, 1997; OSTP, 1999); only emerging areas are highlighted here. The most notable current trend, one driving many of the demands on synchrotron facilities, is the explosion in use of synchrotron radiation in crystallographic analyses of biological macromolecules. This trend will continue.

Each property of synchrotron radiation—brilliance, tunability, time structure, and coherence—can be exploited for research. The hard x-ray beams emerging from the undulators at third-generation synchrotron sources are the most intense ever produced. This brilliance, when coupled with the analytical tech-

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[1] See Appendix D of BESAC (1997).

niques of x-ray scattering, diffraction, spectroscopy, and direct imaging, yields an unprecedented capability to characterize structural and dynamical properties of complex materials. Applications are being made to larger and more heterogeneous systems, with studies possible on smaller and less-well-ordered samples.

The coherence of the x-ray beams from undulator sources excites researchers as much as do their extraordinary intensities. Because of the natural coherence of these sources, x-ray correlation spectroscopy—a method that enables the collective motion of molecules to be studied on length scales as small as nanometers (one billionth of a meter)—is an especially exciting prospect. This technology makes it possible to explore an entirely new world of dynamical phenomena with x rays, a probe normally thought of as capable of yielding only static structures. Laser experiments provide similar dynamical information, but they are limited to the more macroscopic-length scales of hundreds of nanometers. The coherence of third-generation x-ray sources will also enable the development of methods for focusing x-ray beams down to the 100-Å regime, thereby permitting structural characterizations of heterogeneous materials at the nanometer level. X-ray lenses are being developed for hard x-ray microscopes designed to operate in an energy range from 10 to 100 keV.

Synchrotron studies on amorphous and partially ordered systems are expected to become increasingly important. X-ray imaging with microprobes is emerging as a major new technique with applications in the life sciences as well as in materials science and engineering. Nearly every materials science collaborative access team (CAT) at the APS is now developing microprobe capabilities, an activity that was not anticipated in the original plans for these experimental units. There will also be a substantial increase in user need for dedicated small-angle x-ray scattering (SAXS) capabilities both for polymers and for the biophysics community, as anticipated in the Structural Biology Synchrotron Users Organization (1997) report. The importance of high (angular) resolution, SAXS, and diffraction is being seen in structural studies of soft condensed matter (e.g., the ubiquitous polymeric materials) and disordered and partially ordered biological assemblies (lipid membranes, filamentous proteins). X-ray absorption spectroscopy techniques enable not only the identification of trace elements at parts-per-million to parts-per-billion concentration levels but also the determination of their chemical states.

Continued growth of synchrotron applications in the life sciences is assured, especially in crystallographic studies of macromolecular structure, as shown by the record of structural biology publications and user-generated proposals for dedicated beamlines. One trend is toward large macromolecular assemblages such as multiprotein molecular machines, membrane proteins, ribosomes, and viruses. Another is toward structural genomics, the high-throughput analysis of structural representatives from across entire genomes. Multiwavelength anomalous diffraction analysis, made possible by the tunability of synchrotron radiation, is rapidly becoming the method of choice for structure determination

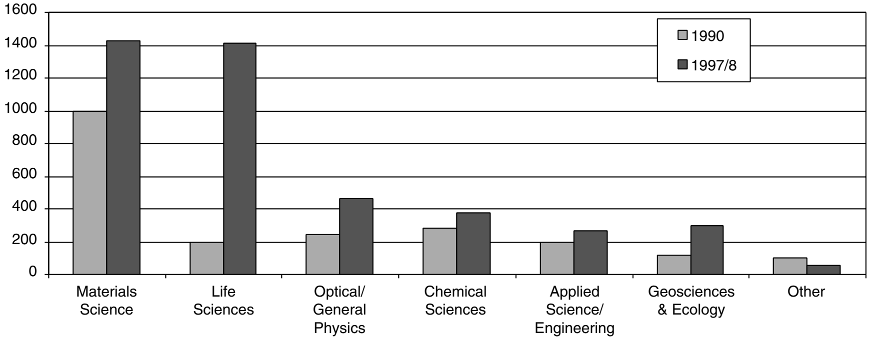

FIGURE 2.1 Number of synchrotron users by field at the SSRL, NSLS, APS, ALS, SRC, and CHESS in 1990 and in 1997 or 1998. Total users: 2,135 in 1990 and 4,296 in 1997 or 1998. The term "users" counts on-site researchers who conduct experiments at facilities. An individual is counted as one user (per facility annually) regardless of the number of visits in a year. Data for the DOE facilities are given for 1997; CHESS and SRC figures are for 1998. (Although the total usage at DOE facilities is known, the breakdown of users by field does not exist for 1998.) The overall number of synchrotron users at all facilities in 1998 was 5,353 (see Chapter 1, Table 1.1).
SOURCE: Information supplied to the committee by Sol M. Gruner, CHESS, on May 5, 1999; James W. Taylor, SRC, on May 17, 1999; and DOE Office of Basic Energy Sciences on June 10, 1999.

(Hendrickson, 1991). Time-resolved crystallography, which exploits the time structure of intense synchrotron beams, is beginning to provide detailed pictures of chemical reactions in proteins (Moffat, 1989).

Trends in the Synchrotron Source User Community

The number of synchrotron users continues to increase rapidly. Data from the four DOE-supported facilities (NSLS, SSRL, ALS, and APS) and the NSF-supported CHESS and SRC facilities show that from 1990 to 1998 the number of users grew by more than a factor of 2.5, from about 2,135 to about 5,353 (see Table 1.1 and Figure 2.1).[2] While the largest increase has been at NSLS and SSRL (primarily because they are the oldest facilities and were among the first to

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[2] Total synchrotron users in Table 1.1 differ from those in Figure 2.1 because the table contains data through 1998 for DOE while the figure shows data only through 1997 for DOE.

offer dedicated beam time), a similar increase is expected at the newer third-generation sources (APS and ALS) (BESAC, 1997).

The change in scientific disciplines of the user community between 1990 and 1997 is also illustrated in Figure 2.1. The number of users from the materials sciences increased from 1,000 to over 1,400, an increase of 43%, but because of the huge increase in number of users, this corresponds to a decrease in fraction of users from 47% to 33%. Users from the life sciences constituted the fastest-growing user community, increasing over sixfold in number and from 9% to 33% of total users. The number of users from the life sciences, the majority of whom are NIH- and NSF-funded, is now comparable to the number of users from the materials sciences. This has raised concerns about the equity of current operations and maintenance support of the facilities and about the future appropriateness of DOE as the steward for many of these facilities. These issues will be discussed further in Chapter 4.

NEUTRON FACILITIES

Snapshot of Current Facilities and Planned Upgrades

Neutron sources are characterized as continuous (provided by nuclear reactors) or pulsed (spallation sources, provided by particle accelerators). The United States has three reactor sources and two spallation sources (Appendix D). All three of the U.S. reactors were commissioned in the 1960s: the High Flux Beam Reactor (HFBR) at Brookhaven in 1965, the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) in 1966, and the Center for Neutron Research (CNR) at NIST in 1969.[3] The NIST facility is the only U.S. source of cold (long-wavelength) neutrons. At this writing, HFBR is not operating, and upgrade plans are on hold.[4] While no additional U.S. reactors are planned in the near future, an upgrade to HFIR, including installation of a cold source and construction of instrumentation, is proceeding (Chakoumakos, 1999). In addition to these facilities, the University of Missouri Research Reactor Center (MURR), commissioned in 1965, provides the highest intensity flux of the dozens of university research reactors in the United States.[5] Since the university research reactors are not national user facilities, they will not be considered further in this study.

The two spallation sources were commissioned in the 1980s: the Intense

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[3] Presentation to the committee by J. Rush, NIST Center for Neutron Research, September 14, 1998.

[4] HFBR was shut down in January 1997 but is planned to be reopened.

[5] Further information on MURR is available online at <http://www.missouri.edu/~murrwww/mission.html>.

Pulsed Neutron Source (IPNS) at Argonne National Laboratory in 1981 and the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory in 1985. A new state-of-the-art spallation facility, called the Spallation Neutron Source (SNS), is planned to be commissioned in 2006.[6] The SNS will be optimized for operation at 2 MW and will produce at least 10 times as many neutrons as any other such source. In addition, an upgrade for LANSCE, which includes the construction of four new instruments for neutron scattering measurements, is proceeding.[7]

Several other countries have built modern and technologically sophisticated facilities in recent years. The Institut Laue Langevin (ILL) facility in Grenoble, France, built in the early 1970s, surpasses all U.S. continuous neutron sources, while the ISIS facility in the United Kingdom, commissioned in 1985, eclipses all U.S. pulsed sources. The ILL and ISIS are, respectively, the most powerful and best-equipped continuous and pulsed neutron facilities in the world. Moreover, there are plans to increase the power of the United Kingdom's ISIS facility and to augment its capabilities by adding a second target station (OECD, 1998). The Swiss Spallation Neutron Source, SINQ, started operation in 1996, and a new German reactor, FRM-II, is under construction with a planned start date in 2001. Current upgrades at the ILL and ORPHÉE reactors promise considerable gains in intensity and efficiency, and there is scope for the installation of new instruments to increase user capacity. The U.S. neutron sources do not compare favorably with those elsewhere in the world.

The inadequate supply of neutrons in the United States (especially cold neutrons), as well as the inadequate and outdated instrumentation of many U.S. neutron facilities, has been found to be an impediment to the scientific productivity of the neutron research community (NRC, 1984; BESAC, 1993, 1998). The committee agrees with the cited review committees' recommendations for source improvement, instrument development, and expanded facility staffing.

Trends in the Scientific Applications of Neutron Sources

Trends in scientific neutron applications have been analyzed in several recent reviews (ENSA, 1998; BERAC, 1998; SNS, 1998). The most rapidly developing areas of research are (1) the use of cold neutrons in the science of polymers and complex fluids (BESAC, 1993), (2) the exploitation of neutron reflectometry, and (3) the extension of small-angle neutron scattering (SANS) to a greater range of scientific problems and sample environments. In the biosciences, growth

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[6] The SNS is a $1.36 billion project supported by DOE to build the world's most powerful pulsed neutron source. The SNS is scheduled to be commissioned in FY 2006; by FY 2008 it is expected to be used annually by up to 2,000 researchers from academia, national labs, and industry. The preferred site is Oak Ridge National Laboratory.

[7] Personal communication from Geoffrey L. Greene, LANSCE, April 13, 1999.

is expected in low-resolution structural studies of multicomponent noncrystalline systems and dynamic studies that probe the relationship between biological function and molecular motion in macromolecules. Applications of SANS and reflectometry to polymers and soft materials will continue to grow, as will applications of inelastic scattering, including the use of neutrons to study adsorbates and in situ catalytic processes. The use of specialized powder diffraction techniques, which enable engineers to measure strain and texture in materials of technological and commercial importance, will show enormous growth, as will the use of conventional powder diffraction patterns to study both atomic and magnetic structure.

The characteristics of neutrons that will be exploited include their electrical neutrality, the atomic number independence of their scattering cross sections, the isotopic dependence of their scattering cross sections, the range of different energy and momentum transfer possible in a scattering experiment, their possession of magnetic moments, and their polarizability. The charge neutrality of neutrons means that they penetrate solids to depths of centimeters, thus enabling studies of bulk phenomena in situ. The isotopic dependence of their scattering cross section (which can be used, for example, to distinguish hydrogen from deuterium) makes neutrons especially useful for studying light atoms in soft materials. Their possession of magnetic moments makes neutrons uniquely sensitive probes of magnetic interactions. Using neutrons, one can simultaneously determine the atomic and magnetic structures of, for example, colossal magnetoresistive materials, which are of interest for high-density magnetic storage media. Both thermal and cold neutrons are useful probes for investigating the structure and dynamics of hard and soft materials over length scales ranging from the atomic to the mesoscopic, 1 to 10^5 Å, and over energy transfers from 10^{-9} to 1 eV (NRC, 1984; BESAC, 1993, 1994, 1998; European Science Foundation, 1996; Finney et al. 1997; OECD, 1998; Richter and Springer, 1998).

The relative advantages of reactor-based and spallation neutron sources depend on the application. Intense, steady beams of neutrons emerge from reactors; if the neutrons must be separated by energy to make a measurement, most are discarded. Short pulses of neutrons are produced by spallation sources, most of which can be captured by time-of-flight methods. Because the number of neutrons detected is the basis of most measurements, each technique has advantages and disadvantages. Reactor sources are superior for most SANS research and for diffraction or spectroscopy requiring a limited range of momentum transfer and energy transfer (e.g., triple-axis spectrometers). Spallation sources are superior for high-resolution powder diffraction over an extended range of momentum transfer and in extreme environments; for one-shot elastic scattering measurements, such as on samples undergoing irreversible changes in response to perturbations; and for surveys of scattering over a wide range of momentum and energy transfer. Spallation sources are also superior for applications using epithermal neutrons (>100 meV).

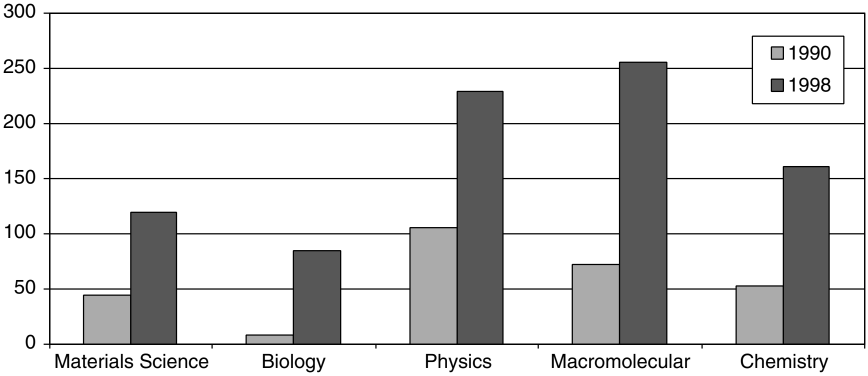

FIGURE 2.2 Number of users by field at the NIST CNR in 1990 and 1998. Total users: 265 in 1990 and 850 in 1998. The term "users" counts on-site researchers who conduct experiments at facilities. An individual is counted as one user (per facility annually) regardless of the number of visits in a year.
SOURCE: Information supplied to the committee by Jack Rush, NIST CNR, on May 4, 1999.

Trends in the Neutron Source User Community

During the 1990s, the neutron user community in the United States grew both in absolute numbers and in the diversity of scientific disciplines. Approximately half of the neutron researchers use the four DOE facilities and half use the NIST facility.[8]

The experience of NIST's Center for Neutron Research, which is the only U.S. source of cold neutrons, is a good predictor of the growth profile for the user community as a whole. As shown in Figure 2.2, at NIST the number of participants grew from 265 (including 60 students) in 1990 to 850 (including 270 students) in 1998—an overall increase of 220%. The composition of the user community also changed significantly over that period. Use by materials scientists, which grew by more than a factor of two in absolute numbers from 1990 to 1998, remained a nearly constant fraction of the users at roughly 15%. Use by scientists doing macromolecular research, which grew by more than a factor of three over this period, increased slightly in fractional terms—from 27% to 30%. The number of scientists doing biological work increased by a factor of 10, from

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[8] The total user figures are provided in Figures 2.2 and 2.3. For 1997, the users at NIST's CNR were roughly as numerous as those at the DOE facilities. However, as noted in Table 1.1, the number of users at DOE neutron facilities declined significantly in 1998.

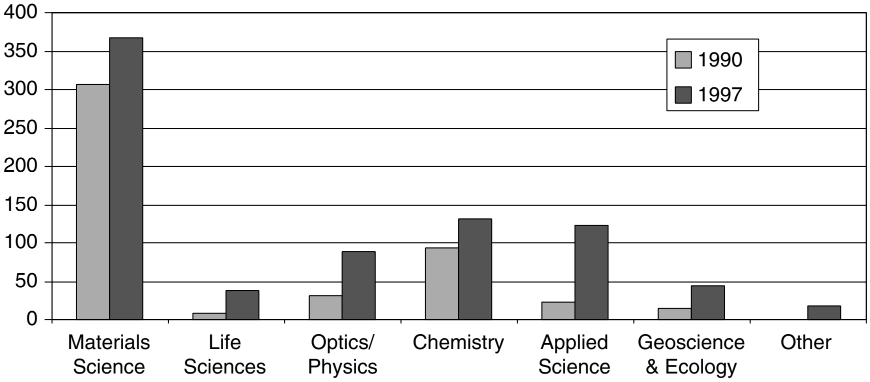

FIGURE 2.3 Number of users by field at the IPNS, LANSCE, HFBR, and HFIR in 1990 and 1997. Total users: 475 in 1990 and 810 in 1997. The term "users" counts on-site researchers who conduct experiments at facilities. An individual is counted as one user (per facility annually) regardless of number of visits in a year.
SOURCE: Information supplied to the committee by DOE Office of Basic Energy Sciences on June 10, 1999.

a very few researchers (3%) to 10% of the total usage. Use by the physics community, which doubled in absolute numbers, decreased in fractional terms.[9,10]

Similar growth was observed in the user communities of the DOE facilities before LANSCE and HFIR were closed for upgrades and HFBR was shut down (Figure 2.3). From FY 1990 to FY 1997, the number of users at neutron sources grew from 475 to 810. The number of materials scientists increased by 20% between 1990 and 1997 (from 304 to 368) and accounted for nearly half the total users in 1997. The number of users in other sciences increased by a factor of over 2.5 to constitute over half the total users in 1997. Part of the difference in distribution between the DOE facilities and NIST comes from the different classification schemes—soft polymers are classified as macromolecules at NIST and as materials at the DOE facilities—and part comes from the existence of the cold neutron facility at NIST, which has attracted users from many nontraditional fields.

While comparable data do not exist for U.S. facilities, the European Neutron Scattering Association survey of the European user community noted that the

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[9] Macromolecular research includes polymer, colloid, and complex fluid studies.

[10] Personal communication from J.M. Rowe, director, NIST Center for Neutron Research, May 3, 1999.

3.6% of users from the life sciences use 10% of the neutron beam time in Europe.[11] The survey also found that more than one-half of the users consider use of neutron beams to constitute less than 50% of their research programs (ENSA, 1998).

HIGH-MAGNETIC-FIELD FACILITIES

Snapshot of Current Facilities and Planned Upgrades

The United States has only one national high-magnetic-field user facility, the National High Magnetic Field Laboratory (NHMFL). Support for the first national user facility, at the Francis Bitter Laboratory at the Massachusetts Institute of Technology (MIT), originally came from the U.S. Air Force in 1960. Project support was shifted to the NSF in 1973, but the facility remained at the Francis Bitter Laboratory until 1995. In 1990 the NSF established the NHMFL. The NHMFL is managed by a consortium of two state universities and one national laboratory, and it is funded by the state of Florida and by the NSF. Today the NHMFL is a worldwide leader in available power, magnetic field strength, and magnet design.

Both continuous and pulsed high magnetic fields are needed in high-magnetic-field research. Continuous high magnetic fields require large power sources to generate steady high-intensity magnetic fields. There are 10 such facilities in the world: six in Europe, three in Asia, and one (NHMFL) in the United States. The U.S. laboratory has the largest power source (40 MW). The next largest (24 MW) is in France, and a new 24-MW laboratory is under development in the Netherlands. Because of its larger power supply, the U.S. facility generates the strongest continuous magnetic field now available in the world.

Pulsed magnets can provide higher peak fields than steady-state magnets because pulsed magnets do not need continuous cooling. Pulsed fields extract energy from a power source to produce an intense magnetic field in a coil for a limited amount of time. Even with modest energy sources, intense peak fields can be generated if the pulse duration time and coil volume (peak field ~ energy/time × volume) are limited. To be useful for experimentation, it is important that the pulse sustain peak values of 50 T or greater in a volume greater than 1 cm^3 with times at peak greater than 1 ms. Attainment of such parameters requires dedicated facilities because the energy source required is large and because of the safety issues associated with the rapid discharge of so much energy into a small volume. For pulsed fields in this range of parameters, there are nine facilities in Europe, four facilities in Japan, and three in the United States (at the NHMFL, Lucent Technologies Laboratory, and Clark University). The largest U.S. facility is at the

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[11] Presentation to the committee by Alan Leadbetter, November 1998.

NHMFL, where a motor and generator system capable of providing 560 MW and 600 MJ is available to drive magnet systems. Due to the size of the power supply, the U.S. facility is the only one capable of producing 100-ms pulses at field strengths of 60 T. A magnet that will deliver millisecond pulses of up to 100 T is under development.

Future advances in the generation of continuous and pulsed high magnetic fields may be limited by the stress limitations of the materials used in magnet construction. Seven of the continuous field facilities are developing hybrid superconducting-resistive magnet systems that will push to the highest possible steady magnetic fields. The U.S. facility should again achieve the highest continuous magnetic field (45 T) once construction of its hybrid is completed.

Trends in the Scientific Applications of High Magnetic Fields

There are two broad areas of magnetic field research: research in producing high magnetic fields and research using high magnetic fields. Research in producing high magnetic fields is needed to generate even higher field magnets, because the highest magnetic fields must be produced with resistive magnets that push the stress limits of materials used in magnet construction. Research in producing high magnetic fields has led to improved understanding of metals, superconductors, semiconductors, organic conductors, and magnetic materials.

Research using high magnetic fields is expanding to include materials sciences, physics, chemistry, biology, and environmental research. High-magnetic-field research is providing new insights into chemical and biological "materials" for medicine (synthesis of new drugs), biology (structure of large molecules), and environmental science (surface reactions and study of remediation pathways). Other developing areas of research with high magnetic fields include energy storage and power conditioning for utility applications; plasma confinement for new energy sources; magnetic levitation for high- and low-speed transportation; large motors for industrial use and ship propulsion; medical diagnostic systems (magnetic resonance imaging); materials characterization systems; materials growth and processing; and magnetic separation.

Research with high magnetic fields has led to the development of magnetic resonance imaging for medical purposes and of nuclear magnetic resonance (NMR) for chemistry and biochemistry. The development of these techniques has relied on the development of advanced magnet materials and on the design and construction of large high-field magnets.

Pushing the science and technology of magnetic fields to the extremes—where the science suggests new discoveries will be made—requires a dedicated center with the specialized talent and equipment to build, maintain, and operate the facility and where user support is provided and education on the benefits of high-magnetic-field research is offered.

There is growing interest in NMR, ion cyclotron resonance mass spectroscopy (ICRMS), and electron magnetic resonance (EMR) spectroscopy in high magnetic fields in order to acquire greater resolution and enhanced spectral sensitivity. Enhanced spectral sensitivity means that the time required to obtain a spectrum of a given sensitivity will be shortened. Advances in NMR probes and data acquisition systems, along with higher-field NMR systems, are also leading to large sensitivity increases. These increased sensitivities permit larger molecules to be studied, which is important to the biological and chemical sciences.

High-magnetic-field NMR systems are expensive, primarily because of the cost of the magnet system. A 750-MHz NMR spectrometer, which is roughly the current state of the art, costs about $2 million and uses a 17.5-T magnet with a stored energy of about 5 MJ. NMR systems operating at 900 MHz are under development. They will require magnetic fields of 21 T with a stored energy of about 35 MJ and cost about $5 million to $8 million. NMR systems of 1,000 MHz will require magnetic fields of about 24 T with stored energies approaching 40 to 70 MJ and costing $10 million to $15 million. Thus the cost, design complexity, and safety issues surrounding such instruments suggest that facility-type operation may be appropriate for them, although the low throughput characteristic of NMR spectrometers raises questions about their suitability as general user instruments. At present the NHMFL operates 15 high-magnetic-field NMR systems.

Trends in the High-Magnetic-Field Facility User Community

Because NHMFL has only been in existence since 1995, long-term user trends do not exist. However, between 1995 and 1998 the number of users increased from 175 to 300 (Table 1.1).[12] Demographic analyses show that the largest usage is in the materials science disciplines, but significant growth in biological and chemical areas occurred from 1995 to 1998.[13] Although this trend is expected to continue as both low- and high-resolution high-field NMR, ICRMS, and EMR studies grow in importance, it may be better to conduct low-throughput activities elsewhere rather than at a user facility. A peer review process regulates user access to the facility. At present, the waiting time for quality proposals is short and meets the requirements of scientific researchers.

COMMON THEMES AND THE IMPLICATIONS FOR USER FACILITY MANAGEMENT

The above discussion shows that the situation at the high-magnetic-field user facility differs from that at the synchrotron and neutron user facilities: the NHMFL

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[12] Presentation and materials provided to the committee by B. Brandt, NHMFL, September 1998.

[13] The number of biological users of the NHMFL increased from 7 users in 1995 (4% of total users) to 29 users in 1998 (10%). Chemistry users doubled from 11 in 1995 (6% of total users) to 22 in 1998 (8%).

facility appears to be able to adequately meet user needs for the foreseeable future, whereas synchrotron and neutron facilities do not appear to be able to adequately meet their user needs. Accordingly, the following discussion of common themes focuses largely on the needs of the synchrotron and neutron facilities.

Funding Issues

Stresses resulting from funding inadequacies are a major concern to both the synchrotron and neutron communities. In the case of synchrotrons, the growth in size of the user community has given rise to pressures for access to beam time: demand for beam time for approved proposals exceeds available time by a factor of approximately two (Structural Biology Synchrotron Users Organization, 1997), although planned beamline construction at existing facilities will likely moderate this pressure in the near term (OSTP, 1999).

In the case of neutrons, stresses arise from the limited supply of neutrons in the United States, especially cold neutrons, and from the gross inadequacy of available instrumentation, as has been pointed out in several studies (BESAC, 1993, 1997). However, the planned construction of the SNS and upgrades at LANSCE are likely to moderate pressures arising from the limited supply of neutrons in the near term.

The dramatic growth in the number and size of the facilities and facility user communities exacerbates the problem these facilities have with the inadequacy of their annual operating funds. This problem, which has been stressed in numerous previous reports (BESAC, 1997, 1998; Structural Biology Synchrotron Users Organization, 1997; BERAC, 1998; OSTP, 1999), was emphasized by all the DOE facility directors who appeared before the committee (see Appendix C). This concern was also the impetus for the DOE Scientific Facilities Initiative of 1996,[14] which provided financial support for the facilities above their appropriated levels. Because of this inadequate direct facility funding, alternative stable sources of facility support must be sought.

User Support Issues

The increasing number of facility users who are not experts in facility technologies is another source of stress for the facilities. While user scientific disciplines have broadened dramatically in the last 10 years in all three types of user facilities (Figures 2.1, 2.2, and 2.3), the trend is most notable in the synchrotron

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[14] In 1996 DOE's Basic Energy Sciencies Division, the steward of most of the user facilities, received an increase of some $57 million for the facilities, a substantial fraction of which went into facility operating budgets. A smaller portion was used to upgrade experimental instrumentation and to fund competitive research proposals. The resulting higher funding level was continued annually. Iran Thomas, DOE, personal communication, June 1999.

facilities, where in 1998, 30% of the users came from the biological community. Typically, these "new" scientist users view the facilities as providing useful data that are, nevertheless, only a small part of their research programs.

The rapid growth of this inexperienced user community has several implications for facility management. First, there must be adequate staff to assist these users in setting up and running experiments to maximize efficient use of beam time. Education and training courses are needed to educate these users about the facility capabilities and relevance to user scientific problems. In addition, on-site ancillary facilities, such as wet laboratories and cold rooms, are needed by many members of emerging user communities, particularly structural biologists, chemists, and materials scientists working with soft materials. The contrast between the excellence of these ancillary facilities at NIST and their condition at the DOE neutron facilities is striking. Finally, equipping and adequately staffing new beamlines dedicated to high-demand experiments, such as protein crystallography, would minimize setup time and optimize beam usage.

Educational offerings for new users, as well as refresher courses for more experienced users, are important components of user support. Neutron, synchrotron, and combined neutron/x-ray-scattering short courses, workshops, and summer schools have been very successful in Europe and at NIST in the United States. Several DOE facilities are jointly offering a combined neutron/x-ray summer school at Argonne National Laboratory beginning in 1999.[15] Teleconferencing and World Wide Web supplementary materials can expand the audience for such schools and enhance participant experiences.

Management Issues

The increasing diversity of the user community may also lead to a mismatch between the mission of the steward and the interests of the user communities, which in the case of its biological component is supported mainly by NIH. In some cases this mismatch can be managed by placing responsibility at a higher (more generic) level in the steward agency. In other cases a transfer of stewardship to an agency with a mission more congruent with the user facility's dominant scientific program may be appropriate. Conversely, a potential agency may not have the culture or experience to operate a large facility. In any event, mechanisms for closer interagency cooperation are needed to make such decisions and to allocate responsibilities for funding of facility capital improvement and operating expenses.

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[15] These courses are funded by grants from DOE.

Legal Issues

Legal issues of concern involve user agreements and intellectual property rights. The former range from simple to onerous and vary depending on whether the research is proprietary and the facility at which the research in conducted. Simplifying and standardizing the user agreements could alleviate some of this concern. Intellectual property rights issues significantly affect facility usage, and the committee wishes to bring attention to these concerns.

These themes and their implications for user facility management are developed further in the following chapters.

3

Management Models

User facility management has evolved dramatically over the last three decades in parallel with the equally dramatic growth in use of the facilities. The facilities have been phenomenally successful in their impact on both science and society; so far, management of the facilities has been able to cope successfully with the increasing number of users, changes in scientific disciplines, and stringent budgets. While the current management model, the steward-partner model, has proved successful, modifications can be made to enable it to better accommodate changes in usage and budgetary limitations. In this chapter the successes and limitations of past and present management models are reviewed as a basis for formulating a cooperative stewardship model, which will be discussed in Chapter 4.

BACKGROUND

Single-Agency, Single-Mission Model

Initially, such research facilities as particle accelerators and neutron reactors were built for a single purpose (e.g., high-energy or nuclear physics research), and they were managed by a single agency and operated by and for a single scientific community. An example of this model was the alternate gradient synchrotron at Brookhaven National Laboratory, which was funded by DOE and was used primarily for high-energy physics research. Mission and model were well matched in this case, as both the core facility and the user research programs were funded from a common source. This resulted in relatively few management and funding problems.

Early Evolution of the User Facility Model

Each facility discussed in this report—synchrotron, neutron, and high magnetic field—was developed for a different purpose at a different time. Nevertheless, each has evolved into what is recognized today as the operating mode characterized as a user facility. Early synchrotron facilities had a parasitic dependence on electron accelerators. Many early neutron facilities were constructed with multiple purposes in mind (e.g., isotope preparation, as well as beam tubes for research), but facility access to outside users was limited. The National High Magnetic Field Laboratory, on yet a third evolutionary path, was created at the outset as a national user facility.

An example of the evolution of synchrotron facilities is seen in the early days of the Stanford Synchrotron Radiation Laboratory (SSRL).[1] Initially, in 1973, the NSF operated the SSRL for materials science and low-energy physics users. The SSRL had a parasitic dependence on the Stanford Linear Accelerator Center's storage ring (SPEAR). SSRL was, in a real sense, a subfacility attached to the main accelerator facility, which was operated by the DOE's High Energy Physics program. While much pioneering condensed-matter science was conducted at SSRL under this system, parasitic operation satisfied few users and discouraged many potential users of synchrotron radiation because of the limited availability of beam, the poor reliability of beam delivery, and the lack of user control over beam energy. These factors compromised the users' ability to plan experiments and to do science. Nevertheless, the value of neutron and photon sources for multidisciplinary science demonstrated by these measurements led to a new generation of facilities that were dedicated to multidisciplinary use. These facilities were created either by changing the mode of operation of an existing facility, such as the 1983 transfer of SSRL from parasitic operation under DOE's High Energy Physics program to dedicated operation under DOE's Office of Basic Energy Sciences, or by constructing new user facilities.

The parasitic mode of operation is still in effect for the CHESS synchrotron at Cornell, which is dependent on the CESR high-energy physics synchrotron. Both are supported by the NSF, but the prime responsibility for the CESR storage ring resides with the NSF high-energy physics program, while the materials program is responsible for the CHESS subfacility. The operational mode for the Manuel Lujan Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE) could at first glance appear to be parasitic as well. As discussed below, a closer examination of the multiple facilities and missions of LANSCE shows this to be incorrect.

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[1] Keith O. Hodgson, SSRL director, in a presentation to the committee on November 17, 1998.

Dispersed Funding and Management Model

As the facilities initially began to evolve into multidisciplinary user entities, responsibilities for funding and management were dispersed among various divisions of the funding agency, usually DOE. One of the earliest such facilities was the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory. Its impact on the science of materials, solid state physics, and chemistry has been enormous. Because of this impact and the recommendations in major studies, such as the Seitz-Eastman report (NRC, 1984), there has been an increase in multidisciplinary user research facilities in the United States and throughout the world.

At HFBR the operating costs were split among the materials sciences, chemical sciences, nuclear physics, and biological sciences divisions of DOE. This funding method has proved unstable, because a division would reduce its contribution to the support of the core facility—the reactor—when budget constraints arose. This in turn required additional funding from the other divisions to finance facility fixed costs. Soon the other divisions could not afford such an increase, and a facility shutdown was threatened, although ultimately averted. This threat occurred even though everyone agreed that the research carried out was of high quality and in many cases impossible to do elsewhere. Furthermore, with dispersed funding it was not clear who had responsibility for upgrades, safety, and environmental concerns, and this lack of clear responsibility was often exacerbated by pressure by the funding sources on the contractors to operate the facilities at the lowest possible cost.

Because of these real and potential instabilities, the early dispersed funding and management model of multidisciplinary facility operation was superseded by a single-source funding and management model—the stewardship model—with the assignment of responsibility for HFBR to a single division at DOE.

Stewardship Models

Simple Steward Model

By the time new user facilities (i.e., synchrotron light sources, neutron sources, and a combustion research facility) were proposed in the 1970s, it was clear from the Brookhaven experience that dispersed facility management and funding was not satisfactory and that the stewardship model of funding and management was necessary. For DOE facilities, it was decided that a single office of the department would take primary responsibility for funding, development, and management of each multidisciplinary facility. This office was called the steward. This management model was also implemented by NSF and NIST.

Steward-Partner Model

In the steward-partner model, as in the simple steward model, the steward invests in constructing and operating the core facility and some of the beamlines. User research programs and the experimental stations are funded in various ways; some are funded by government agencies, some by industry, and some by the facility itself. The funding organizations are the partners. The proportion of partner-funded to steward-funded experimental stations depends largely on the type of facility.

CURRENT STATUS OF U.S. FACILITIES OPERATIONS AND FUNDING

For most of the U.S. facilities, an agency or a major program within an agency has acted as steward (see Table 3.1), taking responsibility for construction, siting, and most importantly, operation, maintenance, and upgrading of the facility. For many of the photon and neutron facilities, that funding agency is a program office of DOE. NSF funds and manages the Cornell and Wisconsin synchrotron radiation facilities and the NHMFL. The Department of Commerce funds and manages the NIST CNR.

Research Station Support

Two kinds of experimental stations are at synchrotron and neutron facilities: (1) participating research team (PRT) stations, known variously as collaborative access teams (CATs), instrument development teams (IDTs), or spectrometer development teams (SDTs) at different facilities and (2) facility-operated stations, called facility-operated beamlines (FOBs). The details for each facility are presented in Table 3.1. PRT/CATs are more prevalent at synchrotron facilities than at neutron facilities, but this may be changing. The issues of reallocation of beamlines and termination of PRTs are considered in Chapter 4.

The steward-partner model of funding and management has predominated at the synchrotron facilities since the late 1970s, when the Office of Basic Energy Sciences (BES) and DOE built the first dedicated storage ring facility for the condensed matter and materials science user community at NSLS (CHESS does not use this model.) The cost of the NSLS, high for laboratory-based condensed matter and materials science research, was driven by the high cost of the core of the facility and the diverse instrumentation needed to equip the dozens of beamlines. The funding of the core, the hardware, and the highly skilled scientists needed to develop this instrumentation was beyond the budget of the steward agency.

The concept of PRTs was devised to help solve this problem. In this model, a beamline would be developed, funded, and supported by a team of users exter-

TABLE 3.1 Management Responsibilities at User Facilities

Facility	Steward	Experimental Stations[a]	PRT/CAT/FOB Distribution
Synchrotron[b]			
ALS	DOE	39	20 PRTs
APS	DOE	22 sectors	All CATs
NSLS	DOE	72	59 externally staffed PRTs, 13 NSLS-staffed PRTs
SSRL	DOE	33	4 PRTs
SRC	NSF	33	12 PRT ports
CHESS	NSF	9	All FOBs
Neutron			
IPNS	DOE	14	1 PRT
HFIR	DOE	12	2 PRTs
HFBR	DOE	15 on 9 beamlines	9 PRTs when operating
NIST CNR	DOC	20	4 PRTs, including NSF-run subfacility
LANSCE (Lujan center)[c]	DOE	8	All FOBs
Magnet			
NHMFL	NSF, state	37 magnet stations[d]	All FOBs

[a] Not all can be operated at the same time.

[b] NIST operates a small synchtrotron (SURF) with eight facility-operated experimental stations used mainly for optics calibrations. It is not comparable to the other facilities listed.

[c] Instrumented neutron scattering beamlines. Six additional scattering instruments, of which five operated by SDTs are under construction.

[d] These are of various types: NMR facilities, general-purpose superconducting magnets, and resistive magnets.

SOURCE: Information received from the user facilities.

nal to both DOE and the facility. For example, industrial users formed PRTs among their own employees and collaborators to fund, design, construct, and support new beamlines. PRTs comprising universities, combinations of universities and industry, and researchers from other government agencies and other national laboratories were also formed. The PRTs brought significant instrumentation expertise to the development of the beamlines that they would subsequently use in their own research and were able to call on new sources of funds. In exchange for their investment in facility instrumentation, the PRTs were granted exclusive access to 75% of the time at their beam port.

Interagency Support

In the steward-partner management model discussed above, many of the experimental stations are funded by government agencies other than the facility steward. This funding is provided for beamline development, instrumentation, and support either to a principal investigator or directly to the facility. For example, NIH is building beamlines at APS and is part of the PRTs and CATs that build and instrument beamlines at APS, CHESS, NSLS, and SSRL. Currently it contributes over $12 million to the support of these beamlines.[2] NSF funds the Center for Neutron Research (CNR) at NIST. While interagency funding provides beamline development and instrumentation for the facilities, it also encourages expansion of the facility enterprise in terms of number of users, areas of users, and demands on the source. These of course add costs and increase management difficulties for the steward.

Access to Facilities

Facility access depends on user status. PRT members have unrestricted access to as much as 75% of the time on their beamlines (the exact percentage varies with each facility). Members of a PRT make their own time allocations. Non-PRT scientists apply to a facility for beam time. Their proposals are peer reviewed, and awards are based on scientific excellence, suitability of the facility for the proposed research, time requested, and beam time available at the facility. Currently, user agreements must be contracted between a prospective user or a user's institution and an individual facility or, in some cases, a PRT. This may lead to suboptimal use for those users who wish to conduct research at more than one facility. One way to optimize these resources is to have a standard user agreement that is common to a given type of user facility. This idea is discussed further in Chapter 4.

Facility Operations

Management policies concerning user facilities are set by the stewards based on the advice of an assortment of interested participants or stockholders, including user groups and review committees. In general, these groups and committees are facility-based, but broader groups and committees, such as the synchrotron users group, either already exist or are periodically created to study a specific issue, such as the committees that produced the reports in BESAC (1997) and BERAC (1998). Of special note is OSTP's Working Group on Structural Biology at Synchrotron Radiation Facilities (the so-called Cassman committee), which is discussed in Chapter 4.

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[2] Information provided by Judith Vaitukaitis, National Center for Research Resources, NIH, June 1999.

Status of Stewardship Model Use

Synchrotron Facilities

The mixture of PRTs of external collaborators and facility-operated beamlines has become the standard model of operation for the second- and third-generation and even the upgraded first-generation synchrotron sources, as shown in Table 3.1. It has significantly increased the diversity of funding sources for beamlines and instruments.

The steward-partner funding and management model worked reasonably well for many years, but it is increasingly struggling. In the 1980s, when current facilities were being planned, few of the biologists, chemists, and others who now account for a large fraction of the users conducted research at major user facilities; their needs were neither anticipated nor incorporated in the planning or budgets for the facilities. Because much of the instrumentation is developed by the user group in the steward-partner model, it is assumed that the users will at least be minimally familiar with facility operations. As a consequence, little research support is provided for less-experienced users. The growing numbers of less-experienced users are demanding greater scientific support, and the issue of providing such support is causing strains in this operating model for synchrotron facilities.

Neutron Facilities

All neutron sources in the United States except LANSCE and NIST are operated under a simple stewardship model. In this model, funding and operating the facilities are the responsibility of a single agency or major program office in a department (DOE or DOC). LANSCE is a multidisciplinary, multiuser facility, and the Manuel Lujan Neutron Scattering Center is one of its several subfacilities. (Other subfacilities support weapons neutron research, materials irradiation, isotope production, ultracold neutron development, and others). The Defense Programs Office of DOE is the steward for the LANSCE facility; BES provides operating support and instrument support for the Lujan center. Coordinating the multiplicity of user needs in this complex environment is a management challenge. NIST is operated under the steward-partner model.

Historically, the responsibility for instrumentation and beamline construction for neutron sources has rested mainly with the steward. The absence of PRT funding and scientific expertise in an era of constrained agency funding has adversely impacted both instrument development and availability for neutron research. It appears that the current management model for neutron facilities is evolving toward the PRT/FOB (steward-partner) model now used in many of the photon facilities. The current upgrade at LANSCE will include spectrometer development team funding of the construction of several new instruments. The planned Spallation Neutron Source at ORNL will also have a version of user-collaboration beamlines, although the exact mode is still undecided.

High-Magnetic-Field Facilities

The high-magnetic-field facilities present a different situation. The original facility was financed and managed in a simple stewardship model. The original steward was the U.S. Air Force. Project support for this facility was subsequently shifted to the NSF. The present NHFML receives distributed financial and management support, as described in Chapter 2. The steward-partner model has not been used because the steward funds the instrumentation, which is generally less expensive than the beamlines required at photon and neutron beam facilities.

As discussed in the dispersed financing and management model above, this management model is inherently unstable. However, since there are both adequate funds and available time, it suffices.

EUROPEAN MANAGEMENT MODELS

The committee examined the funding and management of European user facilities to determine whether they possess features that could be used to improve U.S. management models. Decisions to locate and build new user facilities and to evaluate and possibly decommission old facilities are made through processes involving studies and workshops run by government funding agencies and national research councils and their equivalent, as in the United States. Europe differs from the United States in that there are two general classes of facilities, national and international. For national facilities the funding of the cores is wholly through government agencies, as in the United States. Funding of the cores of international facilities is through international research councils. For the national facilities in the United Kingdom (ISIS and Daresbury), for example, the funding agency is part of the U.K. government. For the international facilities (ILL and ESRF), the funding is allocated among agencies from participating countries. This method carries with it a potential for instability in that a single member country can endanger the collective effort by reducing its contribution.[3] The instabilities faced by the international facilities in Europe are thus much like those faced by U.S. user facilities under the dispersed funding and management model.

The United States and Europe also differ in the way they fund, develop, and support instrumentation and beamlines. As indicated above, in the United States the steward-partner model has generated a mixture of FOBs and PRTs, with the

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[3] For instance, in the late 1980s the United Kingdom unilaterally reduced its support for ILL, causing serious funding instability and negatively impacting staff morale.

latter often having substantial industrial participation and funding. In Europe, the beamline and instrumentation development and support are almost wholly public, although some PRTs (called collaborative research groups, or CRGs) have been formed at the European Synchrotron Radiation Facility (ESRF) and ILL in France and at ISIS in the United Kingdom.

User access in most European facilities, as in all U.S. facilities, is determined by a peer review process, except for the time allocated to PRT members on their own beamlines. There is no access fee for nonproprietary research. The committee notes that proprietary research is becoming more common, especially among biotechnology users. The current full-cost-recovery charges for proprietary research, the associated intellectual property issues, and the perennial discussion of possible user fees for the general user are all discussed in Chapter 4. These issues are mentioned here only in the context of the ticket system that was recently adopted in the United Kingdom—possibly as an experiment—to introduce some degree of market forces into the allocation of research resources. Under this system, prospective facility users apply for grants to the research council; their requests are reviewed in an open competition with all other proposals (both those involving facility access and those not involving facility access). Successful proposals are awarded “tickets.” Tickets are valued at the cost of the desired resource (e.g., for research involving facility access, tickets for beam time are valued at actual beam time cost). Facility users awarded tickets then apply to the desired facility for scheduling. The idea behind the U.K. ticket system is to compare facility demand with demand for all other types of research support. Although the ticket system appears to give an incentive to the facility to maximize throughput—number of beam hours delivered to ticket holders—its impact on the quality of the facility’s research output has not yet been determined.

There is a spectrum of opinion among users, facility operators, and policy makers on the efficacy of this approach. Since all the funds, whether in the form of tickets or pounds, come from the same research budget, the advantage of the ticket system may be more in gauging relative demands by the scientific community for different modes of research than in producing revenue for the supplier of any specific research resource.

The United States is not a member of any of the overseas international facilities. However, U.S. scientists currently gain access to these facilities through collaborations without paying user fees, just as European scientists typically gain access to U.S. facilities. The viability of the scientific enterprise depends on this open access for scientists from various countries to others’ facilities. The main advantage of the European facilities arises from the commitment of the research councils to fuller support of the facilities than in the United States. The main disadvantage of the international facilities is the inherent instability of their distributed funding mechanisms. Thus, this survey of European user facilities provides further support for the conclusions drawn from the survey of U.S. management models in the preceding sections.

SUMMARY

Early U.S. management models and the European models, based largely on dispersed stewardship and funding, have been shown to be unsatisfactory for the management of multidisciplinary user facilities because of the diffusion of responsibility and the instability of funding. The simple steward model works well as long as the steward has sufficient funds to fulfill its responsibilities. The steward-partner model works well as long as the steward agency funding a facility is also the dominant source of funds for the research programs conducted at the facility and has sufficient funds to fulfill its responsibilities. In practice, funding inadequacies have plagued both models. For example, the inability of the stewards of the DOE neutron facilities to obtain sufficient funding has caused a serious underinstrumentation of the facilities. (This is in sharp contrast to the NIST facility, which is adequately funded and instrumented.) The newer partners in the synchrotron facilities, the life sciences and environmental communities, have come to occupy increasingly more of the experimental usage. As a consequence, there has been increasing pressure for more financial support from these communities both inside and outside DOE. This threatens a return to the instabilities of dispersed funding of earlier days. The solution to this problem is to involve these other communities in support of the steward in a new cooperative stewardship management model, which will be discussed in Chapter 4.

4

Cooperative Stewardship Model

The models for managing user facilities—the simple steward and steward-partner models—have been in place since the early 1980s[1] and have been satisfactory for the provision of facility resources to the scientific community. They are, however, under pressure at the present time.

As discussed in Chapter 2, this pressure is due to the rapid growth in the number of users, the growing diversity of their scientific interests, and financial constraints. In particular, at synchrotron facilities there has been a significant increase in the fraction of users carrying out research in the life sciences. Because the life sciences are largely outside the traditional missions of most stewards and because many of the new users require more facility and staff support than the traditional users, this growth has raised questions about the identity of the appropriate stewards and sources of funding for the facilities. Financial constraints have also impeded funding for state-of-the-art instrumentation at the neutron facilities, so much so that some neutrons produced by the cores may not be optimally used (BESAC, 1993).

The long-standing problem at the nation's user facilities of obtaining sufficient funds to both upgrade the existing facilities and operate them at efficient levels have been exacerbated by needs resulting from current trends in facility usage. In the early to mid-1990s, the decline in constant dollars of the facility

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[1] The models, with their mixture of facility-supported and private-sector-supported beamlines, were described as "reasonably successful" by the Major Materials Facilities Committee in 1984 (NRC, 1984).

budgets forced some facilities to reduce their hours of operation.[2] In 1996, to increase both operating time and staffing levels, DOE received extra funding through a special facilities initiative.[3] As a result of this initiative, for example, the Intense Pulsed Neutron Source at Argonne National Laboratory reported that beam time available to users increased by 50%.[4] More recently, strains on steward budgets have been addressed by a novel cost-sharing arrangement between DOE and NIH for an upgrade of the core at SSRL and NSLS that was the result of interagency cooperation on issues of mutual concern (Service, 1999) (see Box 4.1). However, while ad hoc solutions to recurring problems have appeared in the past, they do not resolve what seems certain to be a continuing problem.

Given the desirable characteristics of the current simple steward and steward-partner models, the committee believes their basic outlines should be retained. However, there are issues arising from budgetary constraints and changes in the user communities that transcend the purview of any single steward agency. There is, therefore, a need for stability in steward-partner agency coordination.[5] In this chapter the committee articulates the elements of the basic steward-partner model, along with a proposed mechanism to enhance interagency cooperation. The committee calls this the cooperative stewardship model.

MANAGEMENT RESPONSIBILITIES

There are two components to multidisciplinary user facilities: the core of the facility and the individual experimental units, and this division leads to a natural division of management responsibilities (Box 4.2). Responsibility for the core components should reside with the steward. Responsibility for the experimental units, including the training and support of new users, could also reside with the steward; alternatively, it could reside with the sponsors of the experimental units, the partners, which could be either other government agencies or organizations in the private sector.

For synchrotron radiation facilities, the core includes the storage ring, the injector, and the buildings that house the facility; for neutron sources it includes

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[2] Facility operating budgets are dominated by fixed expenses; a relatively small proportion of the budgets is discretionary spending, which affects the services users care most about. When overall budgets are reduced, user services are affected disproportionately.

[3] DOE's Basic Energy Sciences Division, the steward of many of the user facilities, received an increase of some $57 million per year for the facilities, a substantial portion of which went into facility operating budgets. A smaller portion was used to upgrade experimental instrumentation and to fund competitive research proposals. Iran Thomas, DOE, personal communication, June 1999.

[4] Bruce Brown, IPNS, in a presentation to the committee.

[5] Several recent reports have called for greater interagency cooperation to increase operating efficiency at the facilities. See, for example, Structural Biology Synchrotron Users Organization (1997) and BESAC (1997).

BOX 4.1
Description of the OSTP Working Group on Structural Biology at Synchrotron Radiation Facilities (Cassman Committee)

Participants:	Steward and partner agencies that support research in structural biology at synchrotron radiation facilities (NSF,[a] NIH,[b] DOE,[c] NIST).
Issue:	Increasing demand for synchrotron radiation for x-ray crystallography of biological materials.
Rationale:	The awareness at the highest levels of NIH that continued progress in achieving its scientific mission depends on the availability of state-of-the-art synchrotron facilities.
Background:	Recognition that life sciences occupy a large fraction of synchrotron beam time (~30%).
Convener:	OSTP—to provide a neutral venue and a facilitating function.
Input:	Prior studies (BERAC, 1998; BESAC, 1997; Structural Biology Synchrotron Users Organization, 1997).
Action:	Recommendations for staffing, equipment, instrument development, access, and facility upgrades.
Future:	Continue to monitor existing interagency efforts, consider new opportunities, and address other needs.

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[a] Directorate for Biological Sciences.

[b] National Institute of General Medical Sciences and National Center for Research Resources.

[c] Office of Basic Energy Sciences and Office of Biological and Environmental Research.

BOX 4.2
Steward-Partner Model for User Facilities

Steward Responsibility: Core Facility
Construction
Operation
Facility performance reviews
Participating research team performance reviews
Facility upgrades and R&D
Laboratories (general)
General training (e.g., safety and general facilities)
Facility staffing
User support for facility-related issues

Partner Responsibility: Individual Experimental Units (Subfacilities and Beamlines)
Construction
Operation
Laboratories (wet labs, cold rooms, etc.)
Instrumentation (development, upgrades, and provision)
Training (for users at subfacilities and beamlines)
User support for experiment-related issues

the reactor or spallation source, the guidehalls, and the buildings; for the magnet lab it is the high-field magnets. The steward's responsibility for the core includes construction, operation, research and development, upgrades, central support laboratories, staffing, and training.

The nature of the experimental units depends on facility type. For synchrotrons, an individual experimental unit may be a specific beamline and its associated instrumentation or a set of beamlines, typically associated with one sector of the storage ring. For neutron facilities, experimental units could be the instrumentation associated with a specific port. For the magnet lab, they are the instrumentation associated with the different magnets. For neutron and photon facilities, there are ancillary facilities (e.g., sample preparation rooms and cold rooms) that are part of the experimental units. If the individual experimental units are sufficiently large they too may become involved in subfacility construction and operation, training, and the pertinent laboratories.

Role of the Steward

The steward should be the sole operating authority for a user facility. This means that management responsibility for the design, construction, operation, maintenance, and upgrading of the core of that facility rests with the steward. Additional stewardship responsibility extends to general policy issues, such as user agreements, intellectual property rights, performance evaluation, and safety training for users, as well as the coordination of strategic and financial planning with partner agencies. The decision to terminate a facility also resides with the steward. One agency or division of a federal agency may be the steward of several facilities. Alternatively, each individual facility may have a separate steward.

Ideally, Congress should ensure that sufficient resources are available to enable the stewards to provide stable operation of its core facilities in and beyond their mission areas. If this mode of funding cannot be achieved, cost-sharing arrangements to support upgrades or even operating expenses of the core facility may need to be negotiated among steward and partner agencies. (See the "Funding Responsibilities" section of this chapter.)

The steward should have the experience, culture, and infrastructure to manage its stewardships. Its mission should be to advance, apply, and promulgate the science and technology that support its facility. Advancement is achieved by the support of an in-house scientific research program to enhance the science and technology required to deliver high-quality beams of photons or neutrons, or high magnetic fields. Application is achieved through the support of a robust in-house program in basic research that uses the output of the facility. Promulgation is achieved through education and training programs and staff support for inexperienced users. In addition, because the stewardship model works best when the steward has significant programmatic interest in the research performed at the facility, the steward should support research programs in these areas.

As described earlier, the fastest-growing user segment at many synchrotron facilities—life scientists—is pursuing research interests that are outside the traditional mission of the steward. If the trend continues, a possible change in facility stewardship to an agency whose mission is more congruent with the scientific interests of the predominant user community may become appropriate. The cooperative stewardship model proposed here provides mechanisms to address this issue. (See the "Interagency Responsibilities" section of this chapter.) The identification of the proper steward does not, however, diminish the advantage of a single steward.

Role of the Partners

Partners are user funding organizations that have become stakeholders in decisions concerning the facilities. These decisions include the need for a facility, the siting of the facility, necessary user instrumentation, R&D for facility improvement, beamline construction, and all aspects of facility performance evaluation. Partners also have a stake in assuring the continuation of operations at a facility the steward no longer wishes to support. Partners are responsible for the construction and operation of experimental units (subfacilities or beamlines), as well as for the support and training of new users on their end station equipment.

In recognition of the dependence of their research on the continued successful operation of the facilities, these agencies and private sector partners should work with the steward agency to address strategic and tactical questions concerning the operation, construction, instrumentation, and upgrading or decommissioning of the facilities and should undertake to provide funding for subfacilities or experimental stations in their mission areas. While there have been admirable ad hoc attempts to develop this relationship, such as the interagency working group that produced the Cassman report, these efforts are neither routine nor continuing. The creation of a stable, permanent mechanism for carrying out interagency coordination is needed to address ongoing facility-related issues.

FUNDING RESPONSIBILITIES

Financing multidisciplinary user facilities, like managing them, has two components, one concerned with the core of the facility and the other with the individual experimental units. The key to the success of the stewardship model is the adequacy and stability of funding of the steward for support of the core facility (as well as any beamlines it chooses to support). At the lowest level, the partner agencies or private sector partners have responsibility for funding their individual experimental units. This funding model creates a relatively simple system that is accountable, responsible, and stable.

Unfortunately, stewards have not always been able to obtain adequate core funding to implement this model successfully. Several recent reports have identified instances of failure to adequately fund instrumentation, as in the neutron facilities (BESAC, 1997), and failure to adequately fund existing facilities—especially for training and support services at the synchrotron facilities (Lawler, 1997).

In addition, the suitability of this funding model has been questioned because of the rapid increase in users in disciplines that are not part of the traditional mission of the steward agencies (e.g., structural biology). The support of these users imposes incremental costs, such as user training and staffing, on the operation of the core facility. The idea that these users defray core operating expenses, as in the early dispersed funding facility model, keeps reappearing despite its history of instability (DOE, 1999).

The committee considered three general approaches to the core funding issue: (1) centralized funding of all capital and operating costs for core facility activity; (2) cost-sharing arrangements among partner agencies to cover one-time capital costs, with a possible extension to include coverage of core operating costs as well; and (3) user fees to defray facility operating costs, including both the core facilities and experimental stations.

Centralized Core Funding

Centralized funding for all capital and operating costs for core activities is the recommended funding method. It has the advantage of concentrating responsibility, accountability, and resources in the steward agency and thus encourages rational planning. It avoids the potential instabilities of the dispersed funding model described in Chapter 3 (i.e., the risk of cessation of operation) that can occur when one agency cannot or will not any longer meet its financial commitments. The shortcoming of this method is that in the absence of sufficient funding, the operation of the facility suffers. In view of current budget constraints and the growing divergence between the scientific interests of the steward agency and the scientific users, this is a growing risk to financial stability.

Cost-Sharing Methods

Cost-sharing arrangements between the steward and partner agencies for support of the core facilities is the next preferred mode. This can be for one-time capital costs or for ongoing support of core operations. The simplest cost-sharing arrangement would be for the partners to fund one-time capital costs for construction of new facilities or for discrete upgrades to the core facility. In this model, responsibility for ongoing core operation and maintenance costs would remain with the steward. NIH and DOE have recently implemented this model through a special cost-sharing arrangement.[6] The committee believes that this is an example of a funding policy for user facilities that should be pursued. The disadvantages are that it requires close budget coordination between the two agencies and their respective oversight committees in Congress; if all parties are not in full agreement, a significant funding gap can occur. If Congress is not fully educated on the funding of the steward and partner agencies, it may use the potential availability of alternate funding sources for facility core construction and upgrades to diminish core support for the steward agency, thus exacerbating the problem.

A more complex cost-sharing arrangement would be for the steward and partner agencies to share in the support of core operations and maintenance. As previously implemented in the dispersed funding model discussed in Chapter 3, this funding method was found to be undesirable because of the instability it introduced into the operation of the facility. Because of this, several recent studies have recommended against cost sharing for facility operations and maintenance (DOE, 1999; BESAC, 1997, 1998). However, because of financial exigency, or as a result of changing user demographics and needs, a shorter or longer period of time of such funding may be necessary. If necessary, a cost-sharing approach for core operating expenses should be developed that includes funding mechanisms to ensure the operational stability of the facilities. The benefits of this necessary temporary arrangement must be weighed against its inherent complexity and the risks described in the section on dispersed funding.

User Fees

The user fee model is currently in effect in the United States only for research conducted by private-sector users, who pay “full cost recovery” for beam time used to conduct experiments for which the results will be kept proprietary. Here user fees are appropriate because the information obtained from the work is not intended to be shared and will, therefore, not contribute to the pool of scientific knowledge. It is important to note, however, that proprietary use accounts for less than 1% of beam time at most facilities, and such payments defray a correspondingly small fraction of operating expenses.[7]

The issue of broadening the sources of support for facility operations at DOE has been considered several times. Most recently, the DOE Office of Inspector General considered whether users should supplement base operating funds either through a cost-sharing mechanism or with user fees (DOE, 1999). The report concluded that the imposition of user fees had the potential to significantly undermine the merit basis of peer review for access to the facilities by substituting the

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[6] NIH has committed to fund part of the cost of upgrades to SSRL and Brookhaven (Service, 1999).

[7] Presentation to the committee by Gopal Shenoy, APS, September 1998.

willingness to pay such fees for scientific merit in the allocation of access. Rather, cost-sharing enhancements to the capability of the facilities, such as instrumentation, capital improvements, and staffing of experimental stations, could be sought. The Cassman committee was even stronger in its recommendation against user fees.[8]

The committee concurs with these findings and believes that imposition of general user fees, which could undermine the current merit-based policy for access to these unique national facilities, is not appropriate. In addition, if these fees were to become a significant component of the operating costs, their fluctuations would introduce unpredictability into the level of facility financing for operations and maintenance. The resulting budgetary uncertainties could, at best, impede rational planning for the upgrades and enhanced instrumentation and, at worst, risk facility shutdowns.

INTERAGENCY RESPONSIBILITIES

The complex and evolving management and financial relationships between steward and partner agencies discussed above demonstrate that issues associated with the continued successful operation of user facilities can no longer be satisfactorily addressed with existing stewardship models. The committee proposes going beyond these management models to a cooperative stewardship model. In this model, the essential roles of the steward and partners are maintained and are supplemented by an ongoing working group, composed of the steward and partner agencies, to address issues involving all stakeholders. The Cassman committee (see Box 4.1) is an important milestone in the evolution of this model that should be pursued. The salient features of this group are the mutual concern of the participants about a shared problem—improved access to beamlines for x-ray crystallographic studies; the existence of relevant reports by several high-level review committees; and the recognition by NIH, a partner agency, of its dependence on the success of synchrotron facilities. The cost-sharing arrangement that resulted from the recommendations of this committee was unprecedented and was a major achievement in interagency cooperation. While interagency cost sharing requires congressional and OMB approvals to be implemented, the existence of an interagency agreement provides a powerful impetus for action.

To implement the cooperative stewardship model the committee recommends the establishment of a standing interagency working group consisting of high-level representatives from the steward and partner agencies associated with the major user facilities discussed in this report. Since the success of such a working group depends on the goodwill of the participating agencies, its function is not to

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[8] "Support of synchrotron operations is not something that can, or should, be accomplished through donations from various agencies or through usage charges" (OSTP, 1999).

usurp the authority of stewards over their own facilities, but to provide a forum for the steward and partner agency representatives to discuss issues or concerns that transcend the purview of a single agency. The committee suggests that the working group be constituted under the National Science and Technology Council of the Office of Science and Technology Policy, which would convene, provide a venue, and facilitate the deliberations of the group. Funding for the group should be provided by its constituent agencies. The objective of this working group would be to maximize the national benefits of the user facilities and minimize instabilities in their operation. This recommendation echoes a recent National Academies' recommendation that a formal process be established to coordinate areas of research that transcend single agencies (NAS-NAE-IOM, 1999).

All the user facilities discussed in this report would fall under the purview of the proposed interagency working group. Subgroups of the main working group would be formed to focus on issues concerning specific source types or scientific fields (e.g., the Cassman committee's initial focus on the use of synchrotrons for x-ray crystallography).

The working group is not intended to duplicate the functions of the many existing oversight committees that review the performance of the user facilities. The working group would rely insofar as possible on data assembled by previously existing review committees and other stakeholders, such as user groups and organizations. The role of the working group would be to address those issues that have an interagency dimension, including:

- **Supporting the stewards' budget requests to OMB and Congress for core operations and facility maintenance budgets.** It remains the responsibility of the steward agencies to support the operations and maintenance of user facilities that are operated for the benefit of all stakeholders. The working group would review the stewards' budgets and develop a unified case for funding the steward agencies at appropriate levels, with the partner agencies formally documenting their dependence on the steward's continued successful management of the facility.
- **Monitoring trends in science, instrumentation, and user demographics; recommending any changes in facility capabilities and funding; and identifying needs of potentially underserved scientific user communities.** The working group would regularly review all facilities from a national needs perspective instead of the current process, which typically considers only the facilities of a single steward agency. This would include a review of the needs and opportunities in instrumentation and end stations at the facilities (e.g., the supply and demand for end station instruments, current and planned support levels). To the extent possible, the working group would rely on data, appraisals, or studies conducted by the facilities, review committees, user groups, private sector partners, and the scientific community but would have the authority to commission studies to gather data elsewhere.

- **Periodically reviewing performance appraisals of user facilities to determine whether they are meeting the needs of the user communities and whether the needs of potentially underserved scientific user communities are identified.** These periodic performance appraisals would compare the performances of similar facilities belonging to different steward agencies. They would rely as much as possible on the appraisals of existing user committees and private sector partners at the facilities or in user community surveys.
- **Periodically exploring whether stewardship should be shifted in or between agencies.** This need may arise, for example, if the areas of scientific interest of the facility's dominant user group diverge so greatly from the mission of the original steward that satisfactory user support cannot be provided. While intra-agency transfers are probably a steward agency matter, interagency transfers require interagency cooperation and coordination.
- **Reviewing agency proposals to upgrade, create, or terminate facilities.** The criteria would be meeting of national needs and facility effectiveness. Although the initiative to recommend upgrading, creating, or terminating a facility would continue to rest with the steward agency, the working group would consider the impact of the proposed changes on the steward and partner agencies and on the facilities' user communities. The working group would help prioritize when multiple proposals are involved.
- **Developing guidelines for agency cost sharing.** Guidelines would be based on user requirements and demographics. An example of such a guideline is the establishment of thresholds for the fraction of users supported by a partner agency that, when reached, would obligate the partner agency to support incremental user-related facility costs, such as training or user support. It is important that this be done with appropriate constraints to ensure funding stability.
- **Periodically reviewing user support and training needs.** While such reviews are ongoing at the individual facilities and in individual steward agencies, the working group would provide a forum for considering these factors from the perspective of changing user demographics and responsibilities of the steward and partner agencies to assure adequate staffing and training.

LEGAL ISSUES

User Agreements

User agreements are contracts that must be executed between a facility and its users (or the organizations they represent) before an experiment can be conducted. User agreements vary widely from agency to agency, from facility to facility in one agency, from facility to facility at one laboratory, and even from beamline to beamline at some facilities, depending on whether the user is a member of a PRT/CAT or a general user.[9] User agreements range from relatively straightforward to complex[10] and, more significantly, are not transferable among facilities.[11] User agreements hamper facility use in two ways. The terms of the user agreements are a source of concern to the users' institutions (Service, 1997),[12] and the nontransferability of the agreements increases the legal transaction costs of conducting research at more than one facility and thus prevents the relocation of research programs from oversubscribed to underused facilities.

The controlling policies and regulations concerning user agreements are generally not defined by law but have evolved along with the management and financing systems of the user facilities. In DOE some policies and regulations incorporated in user agreements are mandated by law and some are imposed by the facility contractor. While mandated policies apply to all DOE laboratories and facilities, contractor- and facility-imposed policies and regulations vary broadly. For non-DOE facilities, user agreements have evolved consistent with the general usage of the host institution.[13]

To enhance the usage of the national facilities, increase the flexibility of users to use the available resources of all facilities, and simplify negotiations, the stewards should require their facilities operators to have consistent and simple user agreements. The next step would be for the stewards to require the transferability of a satisfactorily executed user agreement between comparable facilities under their stewardship. Finally, the working group should facilitate the creation of a user agreement that is transferable among all comparable user facilities independent of steward agency.

Intellectual Property Rights

One of the most notable changes in the scientific environment over the last few decades has been the greater attention and interest paid to the commercialization of scientific research. As a result, intellectual property rights have become a paramount concern to an increasing number of users. Intellectual property rights significantly affect facility usage, and the committee chose to include a discussion of them in this report with the objective that they be further considered in another study.

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[9] For example, the APS at Argonne National Laboratory has 14 user agreement forms differentiated by the various categories of users (individual user, member of a collaborative access team, etc.) and whether the research is proprietary or nonproprietary.

[10] For instance, the NIST CNR requires only a simple agreement, while at a comparable DOE facility the agreement is far more complex.

[11] All DOE facilities discussed in this report are operated by contractors, and the user agreements are executed between the user's organization and individual contractors.

[12] Some university users are uncomfortable with the liability and indemnification requirements. Presentation to the committee by S. Dierker and P. Allen on November 17, 1998.

[13] For example, the SRC at the University of Wisconsin has no standard user agreement but operates under the basic guidelines defined by the graduate school policy.

Intellectual property rights and the related issue of proprietary research are contentious issues, especially at DOE-funded facilities (Service, 1997). Under past and current agreements, if users wished the results of their experiments to remain private, they were required to contract for and pay “full cost recovery” for proprietary research. However, as a result of language inserted in the budget bill of 1999,[14] it is not clear whether payment for proprietary research will protect such research results from public disclosure. This is a serious issue for all users.

The policies and regulations governing intellectual property rights at DOE-owned facilities originated in the 1954 Atomic Energy Act, as amended, and the 1974 Federal Nonnuclear Energy Research and Development Act.[15] The Atomic Energy Act vested all intellectual property in the Atomic Energy Commission except where the commission deemed it appropriate to waive its claim.[16] Subsequent legislation[17] enacted to encourage use of the national laboratories provided a blanket waiver to all users under certain conditions.[18] Exactly what constitutes these conditions, which include weapons research and national interest, and where the determining authority lies are themselves unresolved in DOE. The waiver itself is subject to several restrictions, one of which reserves to the government “a nonexclusive, nontransferable paid-up license to make, use, and sell each subject invention . . .” even for inventions for which substantial sponsor resources have been invested. Thus, the issuance of the blanket waiver, which was intended to preserve intellectual property rights and confidentiality for the related background and technical data for the user, also preserved “march in” rights for the government. This is a concern to both academic and industrial users, who must balance the benefit accrued from research conducted or measurements made at DOE national facilities against the risk imposed by the retained government rights. Such considerations tend to reduce the attractiveness of the national facilities.

FINDINGS AND RECOMMENDATIONS

1. **Finding:** The synchrotron, neutron, and high-magnetic-field user facilities in the United States have contributed substantially to the advance of science and technology across a growing range of disciplines. But increases in the costs, management complexity, and diversity and number of users have created a need for a more coherent and better-articulated strategy for managing these facilities.

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[14] P.L. 105-277, Omnibus Consolidated and Emergency Supplemental Appropriations for Fiscal Year 1999.

[15] Codified at 42 USC 2182.

[16] Codified at 42 USC 5908.

[17] P.L. 96-517, the Bayh-Dole Patent and Trademark Amendment of 1980, codified at 35 USC 200-210.

[18] The DOE patent waiver provisions in 10 CFR 784 (1996) supersede earlier patent waiver regulations.

Recommendation: To ensure continued scientific and technological excellence and innovation at multidisciplinary user research facilities, U.S. funding agencies should adopt a cooperative stewardship model for managing the facilities. The elements of the cooperative stewardship model are the following:

- Responsibility for design, construction, operation, maintenance, and upgrading of each facility core should rest with a single clearly identified federal agency—the steward.
- The steward's budget should contain sufficient funds for design, construction, maintenance, operation, and upgrading of the facility core.
- The steward should engage the partners—other agencies, industry, and private institutions—in the planning, design, construction, support, and funding of the experimental stations and other subfacilities. The steward can also function as a partner in, for example, supporting experimental units or joining with others to form user groups.
- The steward should support a robust in-house basic scientific research program. This program should be of sufficient magnitude and diversity to ensure that the steward's mission is addressed and that external users have adequate quality and quantity of collaboration and technical support in their fields.
- The steward should support in-house scientific research to advance the science and technology required to produce high-quality photon and neutron beams and high magnetic fields.

2. **Finding:** As the size and disciplinary diversity of the scientific user community have increased, the programmatic heterogeneity and demands for funding have often grown beyond the scientific expertise and budgets of the steward agencies. Partners have provided assistance to the stewards, but only on an ad hoc basis.

Recommendation: A permanent interagency facilities working group, made up of representation from the appropriate steward and partner federal agencies, should be created under the auspices of the National Science and Technology Council of the Office of Science and Technology Policy to identify issues and to coordinate responses to needs that transcend the missions of the steward agencies. This group should be charged to:

- Review and coordinate support for the facility stewards' core operations and maintenance budget requests to the Office of Management and Budget and Congress.
- Review and, if necessary, prioritize agency proposals to upgrade, create, or terminate facilities based on national needs and facility effectiveness.
- Monitor trends in the science, instrumentation, and user demographics

at facilities and recommend changes in facility capabilities and funding levels and sources as needed.

- Periodically appraise facility performance in meeting the needs of the scientific user communities.
- Periodically investigate the need to shift stewardship of a facility either within or between agencies.
- Develop guidelines for agency cost sharing based on usage.
- Periodically examine user support and training levels to allow for changes in user demographics.

3. **Finding:** Each facility has implicit or explicit agreements with its users that address rights and responsibilities of both parties in such matters as safety, operations, logistics, proprietary research, and costs. These user agreements vary substantially in their complexity and requirements. Among facilities managed by the same steward—and even at the same site—there can be substantial differences that create difficulties for users and reduce the overall effectiveness of the facilities in promoting scientific excellence.

Recommendation: Steward agencies, facility management, and the facility user communities should reexamine and modify their user agreements to achieve maximum simplicity, uniformity, and portability.

4. **Finding:** Some users access the facilities as a relatively minor part of a more comprehensive research program intended to generate results of potential commercial value. Current intellectual property policies, which appear to be a mix of agency-specific legal requirements and facility-generated practices, are complex and uneven across stewards and facilities and may not be appropriate for effective facility use. These factors can inhibit or needlessly complicate participation at the facilities.

Recommendation: The current intellectual property policies and practices at the facilities should be carefully assessed by an independent commission composed of representatives of steward and partner agencies; university, private company, and research institute partners; and user groups. The commission should recommend changes to optimize the protection of researcher and taxpayer interests and facilitate development of scientific findings.

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Appendixes

APPENDIX A

Biographical Sketches of Committee Members

John J. Wise, chair, retired in 1997 as vice president of research after 44 years with the Mobil Research and Development Corporation. Appointed to that position in 1987, Dr. Wise oversaw all of Mobil's research and development in support of the exploration, production, refining, and marketing of petroleum. He was also a director of Mobil Solar Energy Corporation and the Mobil Foundation, and he has authored 20 technical publications and 28 U.S. patents. Dr. Wise served on the Board of Directors of the Industrial Research Institute and received its gold medal for achievement in R&D management. He has worked on several university advisory boards, among them the advisory board of the Center for Advanced Materials at the University of California, Berkeley. He is currently a member of a United Nations panel studying global climate change. Wise has just completed his three-year term as co-chair of the Board on Chemical Sciences and Technology. He received a B.S. in chemical engineering from Tufts University (1953) and a Ph.D. in chemistry from Massachusetts Institute of Technology (1965).

Martin Blume, a former deputy director at Brookhaven National Laboratory, is currently editor-in-chief of the American Physical Society, on leave from his position as senior physicist at Brookhaven. His research interests include theoretical solid state physics, the theory of magnetism, slow neutron scattering, and synchrotron radiation. Before serving as Brookhaven's deputy director, Dr. Blume chaired the National Synchrotron Light Source Department there. Dr. Blume has also served on a number of NRC committees, most recently on the Space Studies Board's Task Group on Alternative Organizations. He received an A.B. from

Princeton University (1954) and a Ph.D. in physics from Harvard University (1959).

Paul A. Fleury is the dean of the School of Engineering at the University of New Mexico at Albuquerque. Before arriving at UNM, he spent more than 20 years at AT&T Bell Labs, where he headed the physics department, then became director of materials and process research in 1993. Earlier Dr. Fleury was vice president for research at Sandia National Laboratories. His major research interest has been the microscopic origin of physical phenomena in condensed matter systems, with emphasis on collective behaviors underlying the magnetic, optical, electronic, acoustic, and structural properties of materials. Dr. Fleury received a B.S. (1960) and an M.S. (1962) from John Carroll University and a Ph.D. in physics from Massachusetts Institute of Technology (1965). He is a member of the Secretary of Energy's Laboratory Operations Board, the National Academy of Engineering, and the National Academy of Sciences.

Jonathan Greer is a senior project leader at Abbott Laboratories in Illinois. Dr. Greer, whose research area is structural biology, served on the DOE Basic Energy Sciences Advisory Committee's Panel on Synchrotron Radiation Sources and Science (a.k.a. the Birgeneau report), which in January 1998 presented its review to the director of the Office of Energy Research at DOE.

Donald U. Gubser has been the superintendent of the materials science and technology division at the Naval Research Laboratory since 1987. He serves as a member of many external advisory boards related to condensed matter physics, and he has been the organizer and co-chair of several international conferences. While at NRL (since 1969), Dr. Gubser has been a visiting scientist at the National Science Foundation and an adjunct professor at several universities. His principal research interests include superconductivity, magnetism, solid state physics, and materials science. He received a B.S. (1963), an M.S. (1964), and a Ph.D. (1969) in physics from the University of Illinois.

Richard L. Harlow is an x-ray crystallographer who since 1977 has been a principal investigator for E.I. du Pont de Nemours & Company. Among his other activities, Dr. Harlow represents DuPont as a board member on the Dow-Northwestern-DuPont Collaborative Access Team at the Advanced Photon Source. This DND-CAT performs experiments in catalysis, polymer processing, and structural analysis. Dr. Harlow has also been an adjunct professor at the University of Delaware since 1981. He received a B.S. from Union College (1964), an M.S. from the University of Illinois (1966), and a Ph.D. in chemistry from Syracuse University (1971). Dr. Harlow has carried out research at all of the national synchrotron x-ray sources (NSLS, APS, SSRL, CHESS) and all the major neutron facilities (HFBR, HFIR, IPNS, LANSCE).

Wayne A. Hendrickson is a biologist with more than 20 years' experience in linking biochemical research with synchrotron sources. He is a leading crystallographer, recently heading a team that determined the detailed structure of the protein that HIV uses to infect T-lymphocyte immune cells. Dr. Hendrickson heads a laboratory at the Howard Hughes Medical Institute at Columbia University. He received a B.A. from the University of Wisconsin at River Falls (1963) and a Ph.D. in biophysics from Johns Hopkins University (1968).

Joseph Hezir is currently a cofounder and the managing partner of EOP Group, Inc., which specializes in regulatory strategy development and problem solving and in identifying newly created government business opportunities formed from mergers, acquisitions, joint ventures, and new markets. He is a member of the Critical Technologies Sub-Council of the Competitiveness Policy Council. Dr. Hezir served for 18 years in the White House Office of Management and Budget (OMB) as an examiner in the environment branch, a senior analyst on government-wide management, and a budget examiner for energy technology programs. From 1986 to 1992, he was OMB deputy associate director for energy and science. He received his undergraduate degree in chemical engineering and completed graduate studies in urban and public affairs at Carnegie Mellon University, specializing in environmental and energy policy.

J. David Litster is a condensed-matter physicist who is currently vice president for research and dean for graduate education at the Massachusetts Institute of Technology. He was appointed to the faculty at MIT in 1966 and became professor of physics in 1975. Dr. Litster's research interests have focused on the experimental study of phase transitions in unusual states of matter, using primarily light scattering and high-resolution x-ray scattering. He is a former chair of the NRC's Solid State Sciences Committee (1993-1995). Dr. Litster is a former director of the MIT Center for Materials Science and Engineering and the Francis Bitter National Magnet Laboratory at MIT. He received a bachelor's degree in engineering from McMaster University in Hamilton, Ontario, and a Ph.D. in physics from MIT.

Lee J. Magid, a professor in the Department of Chemistry at the University of Tennessee in Knoxville, also served as vice president for research and graduate studies at the University of Kentucky (1991-1994). In her research she studies the structure and dynamics of organized assemblies by means of (among other techniques) small-angle neutron scattering and neutron reflectivity. Dr. Magid has held several short-term research appointments at Oak Ridge National Laboratory, ETH-Zurich, and the Max Planck Institute in Göttingen. She is a fellow of the American Association for the Advancement of Science. Dr. Magid received a B.A. from Rice University (1969) and a Ph.D. in chemistry from the University of Tennessee at Knoxville (1973).

Peter B. Moore, a biophysicist and biochemist at Yale University, has experience with all three experimental media considered in this study: neutrons, synchrotrons, and magnetic fields. Dr. Moore has pioneered the development of novel biophysical approaches for obtaining structural information on macromolecules and their assemblies. His neutron scattering analyses of the ribosome and NMR structure determination of ribosomal RNA fragments have enlightened biological understanding of structure-function relationships in RNA machines. He received a B.S. from Yale University (1961) and a Ph.D. in biophysics from Harvard University (1966).

Dagmar Ringe is a professor of biochemistry and chemistry at Brandeis University. Her research group studies the relationship of protein three-dimensional structure to chemical function, using a combination of design of transition-state analog inhibitors, site-directed mutagenesis, and x-ray crystallography. Dr. Ringe received a Ph.D. from Boston University.

Cyrus R. Safinya is a professor of materials and physics and an affiliated faculty member of the Biochemistry and Molecular Biology Program at the University of California at Santa Barbara. Before joining the UCSB faculty, he was senior staff physicist and project leader for x-ray scattering at the Exxon Research and Engineering Company, where he worked on the structure of liquid crystals, complex fluids, and biological membranes. Dr. Safinya's work emphasizes characterization of new structures and intermolecular interactions in self-assembled liquid crystalline and biological systems via modern synchrotron x-ray techniques of high-resolution and small-angle x-ray scattering. He initiated and chaired the first Gordon Research Conference on Complex Fluids (1990) and co-chaired the first Materials Research Society Meeting on Macromolecular Liquids (1989). Dr. Safinya received one of the two Rothschild fellowships awarded annually by the Curie Institute in Paris in 1994. He is a fellow of the American Physical Society (1994) and of the American Association for the Advancement of Science (1997). He received a B.S. in mathematics and physics from Bates College (1975) and a Ph.D. in physics from Massachusetts Institute of Technology (1981).

APPENDIX B

Statement of Task

The charge to the Committee on Developing a Federal Materials Facilities Strategy is given below.

> The study will explore possible strategies to address changing patterns of use of materials research facilities (i.e., facilities that provide synchrotron radiation, neutron beams, and high-magnetic-field environments for investigations in science and technology) and the implications for evolution in the roles of agencies that support research in the relevant areas of science. These strategies would address several objectives: (1) provide a systematic government-wide approach for exploiting materials research facilities in a coordinated and efficient manner; (2) take into account the particular roles and responsibilities of the various agencies involved; (3) consider evolving scientific and technological needs, international changes, and budgetary forces. In the area of scientific and technological needs, particular attention would be given to ways to provide effective support by the facilities and their personnel for the non-expert user community and effective support by federal agencies of the facilities and the research teams and individuals that use the facilities. Ways to identify and educate emerging user communities would be identified.

APPENDIX C

Committee Meetings

The Committee on Developing a Federal Materials Facilities Strategy held three information-gathering meetings during which it solicited presentations from various stakeholders, including facility operators, representatives from funding organizations, user groups, and international representatives. Two meetings of the committee were devoted solely to analysis of information and writing of the final report.

INFORMATION-GATHERING MEETINGS

First Meeting, September 14-15, 1998

Presentations

Orientation to the Science

- Synchrotron Sources - Martin Blume, American Physical Society
- Neutron Beams - John Rush, Department of Commerce/NIST
- Magnetic Fields - Jack Crow, National High Magnetic Field Laboratory

Facility Operations

- Intense Pulsed Neutron Source - Bruce Brown
- Advanced Photon Source - Gopal Shenoy
- National High Magnetic Field Laboratory - Bruce Brandt

Executive Branch Perspectives

- Office of Management and Budget - Elizabeth Robinson
- Office of Science and Technology Policy - Arthur Bienenstock

Agency Perspectives (Roundtable Discussion)

- Department of Energy - Patricia Dehmer
- Department of Commerce/NIST - John Rush
- National Science Foundation - Thomas Weber
- National Institute of General Medical Sciences, NIH - Marvin Cassman

Second Meeting, November 16-18, 1998

Presentations

A European Perspective: Alan Leadbetter, Institut Laue Langevin

Neutron Facilities Roundtable:

- High Flux Isotope Reactor and Spallation Neutron Source - James Ball
- High Flux Beam Reactor - Denis McWhan
- Intense Pulsed Neutron Source - Bruce Brown
- Los Alamos Neutron Science Center - Roger Pynn
- University of Missouri Research Reactor Center - Alan Ketring
- NIST Center for Neutron Research - John Rush

Neutron User Perspective: Ron Briber, University of Maryland

Synchrotron Facilities Roundtable:

- Advanced Light Source - Daniel Chemla
- Advanced Photon Source - David Moncton
- Cornell High Energy Synchrotron Source - Sol Gruner
- National Synchroton Light Source - Michael Hart
- Stanford Synchrotron Radiation Laboratory - Keith Hodgson
- Synchrotron Ultraviolet Radiation Facility - Uwe Arp
- Cornell High Energy Synchrotron Source - Franz Himpsel
- Center for Advanced Microstructures and Devices - John Scott
- Duke Free Electron Laser - Robert Guenther

Synchrotron User Perspective: Steven Dierker, University of Michigan

Magnetic Field Users Group: W. Gilbert Clark, University of California, Los Angeles

User Agreements and Patent Rights of the National High Magnetic Field Laboratory: W. Gilbert Clark and Bruce Brandt, NHMFL

Third Meeting, January 11-13, 1999

Presentations

Stewardship

- Office of Science and Technology Policy - Arthur Bienenstock
- Department of Commerce/NIST - John Rush
- National Science Foundation - Thomas Weber
- Department of Energy - Patricia Dehmer

Neutron Source User Facilities: Iran Thomas, Department of Energy

User Issues, Inelastic Neutron Scattering: Collin Broholm, Johns Hopkins University

The Spallation Neutron Source: Thomas Weber, National Science Foundation

Safety and National Research Reactors: Kenneth Rogers, (former) Commissioner of the Nuclear Regulatory Commission

User Agreements and Intellectual Property Rights: Gilbert Marguth, Department of Commerce

ANALYSIS AND WRITING

Fourth Meeting, March 8-10, 1999

Committee Deliberations

Fifth Meeting, May 12-14, 1999

Presentation

OSTP Working Group on Structural Biology at Synchrotron Radiation Facilities: Marvin Cassman, National Institutes of Health

Committee Deliberations

APPENDIX D

Facilities

The facilities listed in Table D.1 were included in the deliberations of the Committee on Developing a Federal Materials Facilities Strategy.

TABLE D.1 U.S. Multidisciplinary User Facilities

Facility	Funding Agency	Site	Location
Synchrotron			
ALS	DOE	Lawrence Berkeley National Laboratory	Berkeley, California
APS	DOE	Argonne National Laboratory	Argonne, Illinois
CHESS	NSF	Cornell University	Ithaca, New York
NSLS	DOE	Brookhaven National Laboratory	Upton, New York
SSRL	DOE	Stanford University	Stanford, California
SRC	NSF	University of Wisconsin	Madison, Wisconsin
Magnet			
NHMFL	NSF	Florida State University	Tallahassee, Florida
Neutron			
HFIR	DOE	Oak Ridge National Laboratory	Oak Ridge, Tennessee
HFBR	DOE	Brookhaven National Laboratory	Upton, New York
IPNS	DOE	Argonne National Laboratory	Argonne, Illinois
LANSCE	DOE	Los Alamos National Laboratory	Los Alamos, New Mexico
NIST CNR	DOC	National Institute of Standards and Technology	Gaithersburg, Maryland

APPENDIX E

Glossary, Acronyms, and Abbreviations

GLOSSARY

Beamline A corridor through which radiation (synchrotron or neutron) flows from the core facility to experimental instruments. Beamlines can be constructed and supported either by the facility or by outside groups and may provide radiation to multiple instruments.

Cold neutron A neutron beam with especially long wavelengths produced by a reactor. Especially useful in conducting research on the properties of soft matter, such as proteins or polymers.

Core facility The section of a facility producing the basic commodity necessary to conduct experiments, such as the synchrotron radiation, neutron beam, or high magnetic field, but generally not accessed by users.

Dedicated A dedicated facility is one designed from the start to serve optimally the needs of experiments in condensed phase matter rather than high-energy physics. A dedicated beamline or instrument is one devoted to a particular experimental technique.

High magnetic field With current technology, a field above approximately 15 T.

Materials science Study of the structure and dynamics of condensed phase matter.

Parasitic Attached to a core facility to take advantage of the byproduct of the core while it is being operated for other purposes.

Partners Organizations that provide support for research conducted at a user facility, usually for the experimental units. Partners may be federal agencies, state governments, universities, for-profit corporations, or nonprofit organizations.

Reactor A type of neutron source that creates continuous neutron beams through controlled chain reactions involving nuclear fission of certain radioactive elements.

Spallation A type of neutron source in which a particle accelerator directs packets of high-energy protons at heavy metal targets, producing a burst of neutrons that can be used for condensed phase matter research.

Stakeholders Interested participants in the facilities enterprise. These include individual users; facility-based user groups, organizations, and review committees; and more broadly based user groups, organizations, and committees.

Steward The government body responsible for supporting the core of a user facility, generally a federal department or agency with a mission interest in the research conducted and that has the knowledge and experience necessary for construction and operation of the facility.

Stewardship A system of funding, managing, and operating national, multiuser facilities whereby the core facility is entirely supported by one agency: the steward.

Subfacility A subset of a user facility, usually supported by an agency other than the steward, designed to conduct research of a specific type, designated either by field or by type of instrumentation used. Examples are the Center for High Resolution Scattering, supported by NSF at NIST CNR, and MacCHESS, supported by NIH at CHESS, devoted to studies of macromolecular structures.

Synchrotron A device creating radiation by accelerating relativistic charged particles and deflecting them with a magnetic field.

User facility Any site or laboratory equipped to provide the synchrotron radiation, neutron beam, or high magnetic fields required to conduct research into the properties of matter that allows guest researchers to perform experiments to further their own research goals.

ACRONYMS AND ABBREVIATIONS

ALS	Advanced Light Source
APS	Advanced Photon Source
BERAC	Biological and Environmental Research Advisory Committee
BES	Office of Basic Energy Sciences (U.S. Department of Energy)
BESAC	Basic Energy Sciences Advisory Committee
CAMD	Center for Advanced Microstructures and Devices
CAT	collaborative access team
CESR	Cornell Electron-positron Storage Ring
CHESS	Cornell High Energy Synchrotron Source
CNR	Center for Neutron Research (NIST)
CRG	collaborative research group (Europe)
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
EMR	electron magnetic resonance
ENSA	European Neutron Scattering Association
ESRF	European Synchrotron Radiation Facility
FEL	free electron laser
FOB	facility-operated beamline
FRM-II	Neutron Reactor at the Technische Universität Munich, Germany
HFBR	High Flux Beam Reactor
HFIR	High Flux Isotope Reactor
ICRMS	ion cyclotron resonance mass spectroscopy
IDT	instrument development team
ILL	Institut Laue Langevin (France)
IPNS	Intense Pulsed Neutron Source
ISIS	Spallation Source at Rutherford Appleton Laboratory, Oxford, United Kingdom
LANSCE	Los Alamos Neutron Science Center
MacCHESS	Macromolecular Diffraction Facility at the Cornell High Energy Synchrotron Source
MURR	Columbia Research Reactor Center at the University of Missouri
NHMFL	National High Magnetic Field Laboratory
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NMR	nuclear magnetic resonance
NRC	National Research Council
NSF	National Science Foundation
NSLS	National Synchrotron Light Source
OECD	Organisation for Economic Cooperation and Development
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory

ORPHÉE	Neutron Reactor at the Laboratoire Léon Brillouin, Saclay, France
OSTP	Office of Science and Technology Policy
PRT	participating research team
R&D	research and development
SANS	small-angle neutron scattering
SAXS	small-angle x-ray scattering
SDT	spectrometer development team
SINQ	Swiss Spallation Neutron Source
SNS	Spallation Neutron Source
SPEAR	Storage Ring at Stanford Linear Accelerator Center
SRC	Synchrotron Radiation Center (University of Wisconsin)
SSRL	Stanford Synchrotron Radiation Laboratory
SURF	Synchrotron Ultraviolet Radiation Facility
T (tesla)	A unit of magnetic flux density, equal to 10,000 gauss

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MURR	Columbia Research Reactor Center at the University of Missouri
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NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
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