Chapter Two

SYNTHESIS OF THE REVIEWED DOCUMENTS' FINDINGS AND RECOMMENDATIONS

GENERAL OBSERVATIONS

The Science and Technology Policy Institute (S&TPI) research team synthesized the contents, findings, and recommendations of the reports and other documents reviewed for this study. The observations that resulted from this synthesis are broadly applicable to a wide class of federal scientific facilities. These observations should be helpful in understanding the issues surrounding the planning, funding, management, and operation of large scientific facilities.

Facility Missions

- U.S. facilities are generally specialized, with little overlap in their capabilities and missions. The reports we reviewed contained no call for closing facilities to remove redundancy or for any other reason. The panels that prepared the reports generally found that each facility is contributing in its own way to science.
- There is a great deal of overlap and competition between U.S. and international facilities in the areas of neutron scattering and synchrotron sources. National prestige and scientific leadership were cited as reasons for upgrading existing U.S. federal facilities or for building new ones, but technical capability and timely and convenient access by a growing user community are also of great importance for the continued evolution of multi-user, multi-program facilities.
- Although U.S. facilities are specialized, many of them are developing a broader, multi-purpose, diverse, and even interdisci-

plinary research program due to developments in the life sciences in particular. Facilities that had once been the exclusive domain of physicists and material scientists now have much broader user communities.

Access and Usage

- The increased breadth and diversity of research programs introduces increased difficulty in allocating access to facilities in a manner that seems equitable to all users. For example, prioritizing synchrotron beam-time allocation between a materials-science and a life-science experiment is controversial because it is difficult to compare their merits across disciplines.
- Maintenance, staffing, and instrumentation decisions have strongly affected, and in many cases limited, facilities usage. It is important to note that these decisions represent deliberate choices in which trade-offs have been made—e.g., to defer maintenance, to decrease support staff, or to not instrument beamlines in order to reduce funding requirements. These trade-offs are often seen as necessary because of insufficient initial, or incremental and therefore uncertain, funding.[1]

Adapting to Change

- The life expectancy of facilities can be extended significantly through doing facility upgrades, developing broader research programs, and conducting low-cost improvements and robust maintenance.
- The long time frames and uncertainty in building new facilities are often mentioned as justification for shorter-term upgrades, low-cost improvements, and maintenance funding.
- Discoveries motivate new research and experiments, which in turn require new instrumentation or facility capabilities. Assertions that U.S. science requires the building of new facilities

[1]See the “Funding” section later in this chapter for recommended solutions in this area.

need to be weighed against the gains that can be realized through facility upgrades and other such changes.

ASSESSMENT ISSUES

The panels that produced these reports used a wide range of methodologies and approaches to reach their conclusions. In particular, some panels primarily reviewed documents, while others solicited expert input or visited facilities. Also, the degree of internal user-group input varied compared with the degree of input from external users or scholars from other fields.

Although the reviewed reports covered many different facilities, and several types of facilities, they contain a surprising number of common concerns and suggestions. In particular, the report to the Chairman of the Committee on Governmental Affairs of the U.S. Senate on Department of Energy (DOE) major systems acquisitions (discussed in Chapter Three)[2] and the Cooperative Stewardship report[3] (discussed in Chapter Five) contain excellent summations of issues and solutions that cover a wide variety of facilities.

In the following sections, we address the specific concerns of the Office of Science and Technology Policy (OSTP) (as stated in Chapter One) regarding the funding and management of federal science facilities.

MANAGEMENT OF ONGOING OPERATIONS

This section addresses the concerns of OSTP about management efficiency and effectiveness, workforce issues, scientific access to ex-

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[2]United States General Accounting Office, *Department of Energy: Opportunity to Improve Management of Major System Acquisitions*, Report to the Chairman, Committee on Governmental Affairs, U.S. Senate, Washington, D.C.: GAO, GAO/RCED-97-17, 1996 (available at http://www.science.doe.gov/SC-80/sc-81/PDF/rc97017.pdf).

[3]Committee on Developing a Federal Materials Facilities Strategy, Commission on Physical Sciences, Mathematics, and Applications, National Research Council, *Cooperative Stewardship: Managing the Nation's Multidisciplinary User Facilities for Research with Synchrotron Radiation, Neutrons, and High Magnetic Fields*, Washington, D.C.: National Academy Press, 1999 (available at http://books.nap.edu/html/cooperative_stewardship).

perimental stations within these facilities, and maximizing scientific output. It includes key findings and recommendations gleaned from the reviewed reports and synthesized by the S&TPI research team.

Since the early 1990s, significant changes have occurred that provided the background for many of these reports. Of particular interest are demographic changes caused by a growing population of researchers in the life sciences who need to conduct experiments at large scientific facilities, changes caused by the end of the Cold War, and changes due to technological developments.

Important to the understanding of the discussion that follows is the fact that many large scientific facilities work concurrently in two modes—operating the overall facility and operating the experimental stations within the facility. The first mode involves the core operations, maintenance, and modernization of the facility, including the provision of some level of technical assistance to the experimental stations, whereas the second mode typically includes the development, installation, use, and upgrade of the instruments needed to conduct experiments. Given this fact, we consider the effect that personnel, funding, and other administrative issues have on OSTP's core concerns.

Personnel Issues

Personnel issues fall into two categories: (1) technical support at facilities and (2) contract officers and management personnel overseeing facility construction and operation.

Technical support. The reviewed reports imply that the number of staff people available to provide technical support to users strongly influences the productivity of research programs at large scientific facilities. Researchers in the life sciences do not typically have the base of expertise to use facilities traditionally associated with physics and the material sciences without significant technical assistance. As the number of researchers in the life sciences has risen at these facilities, the requirements for staff support have correspondingly risen. Staff support at U.S. facilities is, in general, less than that at foreign facilities of similar types. This staffing shortfall has the potential to place U.S. research at a disadvantage compared with research conducted overseas.

Contract officers and management personnel. A lack of skilled contract officers and management personnel was also highlighted as a concern in the reviewed reports. Although both regulatory and legislative steps have been taken to address this concern, its importance demands that it receive continued attention.

Recommendation. Personnel issues concerning both the numbers and quality of managerial and technical staff are sufficiently similar across federal government agencies with large scientific facilities to warrant attention from the Executive Office of the President. This is not a high-visibility issue, but it has the potential to negatively affect scientific productivity at federal facilities. OSTP, through the National Science and Technology Council (NSTC), should monitor this aspect of the nation's scientific health on a routine basis using well-defined goals and metrics.[4]

Funding

Funding issues constituted a large portion of the reviewed reports. In considering these issues, it is necessary to view them in the bigger picture of national and world events. One report, for example, viewed the cancellation of a number of major DOE acquisitions as negative events, despite the fact that they were nuclear-weapons-related facilities canceled due to the end of the Cold War—arguably a good outcome.

Of specific concern in this study, however, are issues concerning how facilities are funded, for both construction and operation. In 1996, the Office of Management and Budget (OMB) issued a directive requiring that federal departments and agencies request full funding for facilities construction in congressional authorization language.[5] This change is likely to alleviate funding shortfalls that originate from a lack of authorized construction funding. In the past, two approaches have been taken to funding facilities operations: single-

[4]This recommendation is limited to federal government facilities; no assertion is made about facilities that are not owned, operated, or funded by the government. Furthermore, the NSTC will need to define the metrics and goals for managing this issue.

[5]For specific references to changes in OMB directives and statutes, see Chapter Three.

agency funding and splitting the funding among the agencies that conduct experiments at the facilities.

It is clear that consistent funding is needed for both construction and core facility operations, and that dividing up funding responsibility across agencies would require that each agency budget appropriately and in coordination with its partner agencies, and that each associated congressional appropriations subcommittee provide the needed funds. Should one or more agencies change their priorities, or should one or more appropriations subcommittees not supply the needed funds, the ability of a facility to function would be threatened.

Experimental stations at facilities, however, are typically not fully funded by the steward agency. As user demographics diversify, user communities (as represented by agencies, consortia, or other collections of scientists and engineers) are expected to contribute to the funding effort. To do this, teams of researcher organizations, generically called Participating Research Teams (PRTs),[6] obtain funding (primarily federal) for instrumentation and experimentation. This arrangement seems to work well, despite minor problems, which are highlighted in the reviewed reports.

Recommendation. The findings of the Cooperative Stewardship report, which are covered in Chapter Five, were validated by the other reviewed reports: (1) A single agency should fund core operations and maintenance (the "stewardship model") because relying on multiple agencies to fund core functions can lead to shortfalls if agency missions change or if appropriations subcommittees of the Congress disagree on priorities; (2) funding for instrumentation and experimental stations should come from user groups as well as from the steward agency and should be coordinated by an interagency body; and (3) OSTP, through the NSTC, should work with the federal agencies representing this increasingly diverse user community to ensure adequate management and funding of instrumentation and experimental stations. The OMB should play a key role in this interagency coordination process.

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[6]PRTs typically finance beamlines or experimental stations and in return get 75 percent of the available experimental time, with the remaining 25 percent open to general users. Here, we use the term PRT to signify all such cooperative arrangements, no matter what their formal name might be at a given facility.

Access

Legal and administrative issues (e.g., liability agreements, intellectual property rights, financial agreements) are important for ensuring that scientists have access to facilities and for maximizing scientific output. These facilities are typically very busy, with long waits for experimental facilities being the norm. Currently, each facility has its own access criteria, processes, and legal agreements that must be executed before experiments can be conducted. Scientists, or the organizations they represent, must execute legal and administrative agreements with each individual facility they wish to use, even though the different facilities may be operated by the same agency (e.g., the DOE or the National Science Foundation [NSF]) and are all operated by the federal government. Streamlined, transparent, and standardized legal and administrative processes and documentation at the agency or federal government level would improve access to these facilities and could increase scientific output.

Recommendation. OSTP, through the NSTC, should coordinate the development of a streamlined, transparent, and standardized set of legal and administrative practices and a process for implementing those practices at federally owned facilities. In doing so, care is needed to make sure new, nontraditional users become familiar with how access and resource allocation decisions are made.

Life-Cycle Planning

A widely accepted approach to improve management of any major program is life-cycle planning. Several key observations with respect to facility life-cycle planning and the national scientific base represented by large facilities are important to understanding and addressing life-cycle issues.

The first observation is that the installed federal scientific base should be viewed as a single entity and managed accordingly. This perspective has significant implications for issues ranging from facilities funding to the location of proposed scientific facilities.

It is also evident that there is a great deal of uncertainty in defining life-cycle costs. For example, new construction cost overruns were often attributed to changes in the understanding of science, new technology, or requirements that emerge during lengthy construction periods. This uncertainty is particularly acute with first-of-a-kind facilities but can be managed given realistic expectations and competent management.[7] For example, Gary Sanders of the Laser Interferometer Gravitational Wave Observatory (LIGO) told S&TPI researchers that

> . . . while one can learn from other facilities . . . real life-cycle costs emerge from the first several years of operation, and this experience permits more reliable planning during operations. For this reason, the requirement that new facility projects include an up-front enumeration of operating costs and plans must be followed with some expectation that experience will correct even the most diligent plans.[8]

Furthermore, as mentioned earlier, technology often develops in ways that affect life-cycle planning during the very lengthy planning and building stages of large facilities. This is particularly true for technologies such as information technology that have very short development cycles. For instance, Sanders told S&TPI that

> information technology in 2003 is very different from 1994 when LIGO construction really began. With the development of parallel processing arrays (Beowulf) today, our capabilities to produce science are much greater. Our collaborator network and our operating plan have undergone considerable evolution as a result. With the emergence soon of Grid technology, another level of change will take place. [9]

Facilities often have useful lives that far exceed original plans. The Hubble Space Telescope is a good example; its extended life has been caused as much by residual operating capability as by delays in fielding follow-on capabilities. Additionally, as noted earlier, facility

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[7]See the review of the reports on the Laser Interferometer Gravitational Wave Observatory (LIGO) in Chapter Twelve.

[8]From an e-mail exchange between Gary Sanders, LIGO Laboratory, California Institute of Technology, and Aaron Kofner, S&TPI, February 5, 2003. This observation and the ones that follow by Dr. Sanders are particularly useful, given that LIGO is highly acclaimed as a superlative management success.

[9]E-mail exchange, Sanders and Kofner, 2003.

upgrades often make the much more expensive construction of new facilities unnecessary or permit the construction to be significantly delayed. Changing political or economic circumstances have also frequently delayed or canceled the fielding of new facilities. Planners need to explicitly account for upgrades as a normal part of a facility's life-cycle management and development.

The existence or development of user communities is an important item to consider in life-cycle management, and the geographic location of facilities plays an important part in access for scientists. The reviewed reports clearly indicate that the scientific community tends to use the nearest acceptable facility, even when more-advanced facilities exist elsewhere. Furthermore, for a first-of-a-kind facility, there may be no user community in existence when this type of project begins. This lack of a user community creates uncertainties in planning and cost estimation. On this topic, Gary Sanders of LIGO said:

> Another very significant impact on life-cycle costs is the nature of the scientific community that grows around a facility. When LIGO was approved for construction, it was envisioned as operated by Caltech and MIT with several tens of collaborating scientists from a handful of universities. Just a few years into our first round of operating, we are the focus for 38 institutions and more than 400 scientists with several international partnerships. Our program is much more active than imagined, and early life cycle plans have had to be changed.[10]

Among the reports and other material the S&TPI team reviewed are the National Aeronautics and Space Administration and NSF handbooks for facilities management that yield further insights into life-cycle management issues.[11]

Recommendation. In planning for new facilities, particularly unique or first-of-a-kind facilities, flexibility in expectations for life-cycle costs is necessary. This is not to say that "anything goes," but rather that realistic proposals, based on the best cost estimates, must be updated at set periods by competent management teams.

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[10] E-mail exchange, Sanders and Kofner, 2003.

[11] See Chapter Four and Chapter Eight for summaries of these handbooks.

Furthermore, despite long-term planning for future facilities, capability upgrades and modernization should be explicitly considered in life-cycle planning given that the reviewed reports clearly indicate that those steps will be needed.

CONCLUSION: THE NEED FOR GREATER COORDINATION AND NEXT STEPS

In managing and planning the collective base of large scientific facilities, it is clear that interagency coordination led by an authoritative body able to convene suitable interagency meetings and set policy is critical. No single agency has a complete perspective on all ongoing efforts and plans and can make well-informed objective recommendations on priorities, funding, and other systemic issues. As the entity within the Executive Office of the President charged with coordinating and setting government-wide science and technology policy, OSTP (through the NSTC) has the potential to bring the disparate players together to identify and resolve national-level issues. Therefore, OSTP is the logical candidate to lead this process.

A document of the scope of this report can explore only a few general themes and present a few specific recommendations. Nevertheless, these themes and recommendations, coupled with a robust NSTC process to oversee and provide guidance to agencies owning large scientific facilities, should yield significant improvements in the planning, operation, and management of large U.S. science facilities.

A logical next step would be to conduct an analysis of policies governing the development, operations, and maintenance of the collective large-scale federal scientific facilities, which constitute a significant portion of the federal scientific base. Although this analysis is beyond the scope of this study, it could yield valuable insights into the conduct and potential of federally supported science and technology efforts and lead to significant improvements in both.