

Funding and maintaining infrastructure to support the conduct of science have long been central components of federal research and development (R&D) policy. In particular, the federal government manages and operates several large-scale research facilities of various types that enable scientific inquiry in a range of fields, including high-energy physics, astronomy, and, increasingly, the life sciences, in which the United States seeks to retain global leadership. Many of these facilities are long-lived and serve multiple user communities, although this is not always the case (e.g., the Hubble Space Telescope, discussed in Chapters Ten and Eleven, has a narrower user community than do most other federal research facilities, and the Laser Interferometer Gravitational Wave Observatory, discussed in Chapter Twelve, has an even narrower user group).

These facilities pose complex management challenges throughout their life cycles, from initial planning for their creation, through operation and upgrades, to retirement and environmental cleanup. Constructing such facilities requires extensive planning and foresight. Program and facility managers frequently have to adapt to changes in the scientific fields they support, changes in their user communities, and changes in the policy and funding environments in which they compete for resources.

### **STUDY PURPOSE AND SCOPE**

The purpose of this study is to help the Office of Science and Technology Policy (OSTP) address the issues surrounding the planning, operation, and management of selected large scientific facili-

ties and to identify key areas in need of oversight or coordination by OSTP through the National Science and Technology Council.<sup>1</sup> Our ultimate aim was to identify lessons that would be of value to the federal government as it builds, manages, and retires these facilities in the future.

To do this, RAND's Science and Technology Policy Institute (S&TPI) examined 20 reports on studies of, or related documents about, major science facilities, and drew conclusions based on the findings and recommendations of the expert panels that produced this collection of documents.<sup>2</sup> The information presented in this report represents S&TPI's synthesis of the findings and recommendations in those reviewed documents.

It is important to underscore the point that S&TPI did not independently evaluate these facilities, but instead relied on the findings and recommendations reported in the reviewed documents. However, the RAND research team drew from the panels' expertise and methodologies to produce the findings and recommendations presented in this report.

In general, each reviewed report presented an overview of the methodology used to conduct each study, but did not discuss specific metrics or techniques the authors used to reach their conclusions. Notes on the methodologies used by each study panel are included in this report, if methodology discussions appeared in the original reports.

This report distills from the 20 reviewed documents lessons learned about the following issues of particular interest to OSTP and makes recommendations to the extent that they are supported by the documents RAND reviewed:<sup>3</sup>

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<sup>1</sup>This report was limited to facilities owned, operated, or funded by the federal government. No generalization to private-sector scientific facilities is implied by the findings in this report.

<sup>2</sup>This collection of reports is not comprehensive, but rather is a sampling of reports that focused on certain types of large scientific facilities.

<sup>3</sup>We explicitly addressed these items when writing the "Findings and Recommendations" sections of the following chapters.

- Issues regarding facility management effectiveness and efficiency
- Issues regarding accessibility of facilities to scientists
- Issues that affect the quantity and quality of scientific output
- Workforce (both technical and managerial) issues
- Issues of facility life-cycle management, including facility
  - planning and construction
  - instrumentation
  - modernization and modification
  - shutdown or retirement.

These topics clearly are not mutually exclusive and were not uniformly addressed in the reviewed reports. Most reports focused on operations, management, and upgrades for existing facilities, and paid scant attention to the retirement of facilities and only slightly more attention to facilities planning and construction.

## **STUDY APPROACH**

The S&TPI team worked with OSTP to identify documents to be reviewed. The team started with a list of reports recommended by OSTP that focus primarily on National Science Foundation and U.S. Department of Energy (DOE) facilities. S&TPI then conducted a literature search to identify additional reports on large scientific facilities from other agencies that would provide a broader sampling of the scientific community and address some or all of the issues of interest to OSTP (e.g., reports on the Hubble Space Telescope, General Accounting Office [GAO] reports, handbooks for facilities management).

The final collection of reviewed reports, which was approved by OSTP, contained various kinds of documents, including reports by the National Academy of Sciences, reports prepared by government advisory panels (e.g., the Basic Energy Sciences Advisory Committee), other government panels, and handbooks developed for managers of large government projects. All of these documents were

authored by panels of experts who usually represented a diverse set of disciplines appropriate for the purposes of the particular study. However, these panels were often, and perhaps unavoidably, drawn from communities with interests in the construction of new facilities and/or the continued existence and expansion of existing facilities. Although this point is not meant to question the objectivity of the individual panel members, it is worth noting nevertheless.

The scope of this project, as well as time and resource constraints, did not permit a comprehensive review of reports on all types of large scientific facilities. In particular, reports on classified facilities (e.g., those that produce materials for nuclear weapons) and some types of high-energy physics facilities (e.g., particle accelerators) were not included in this review.<sup>4</sup> In fact, the reports on DOE facilities were limited to those run by the DOE Office of Science.

Using a template structured to address the issues of concern to OSTP, the S&TPI team prepared summaries on each of the reports and other documents that were reviewed. Those summaries appear in Chapters Three through Twenty. Drawing from the findings and recommendations of these reports, and from conversations with experts inside and outside of RAND, the S&TPI team synthesized the main recommendations and observations of the reports. These recommendations present useful, prescriptive guidelines and principles for the management of research facilities. Management principles and observations relevant to only a small class of facilities can be found in many of the reports summarized in Chapters Three through Twenty.

## ORGANIZATION OF THIS REPORT

Chapter Two presents S&TPI's synthesis of the findings from its review of the reports and other documents. Short summaries of each report appear in the chapters that follow.

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<sup>4</sup>However, a discussion of these facilities was included in a GAO report to the Chairman of the Committee on Governmental Affairs of the U.S. Senate entitled *Department of Energy: Opportunity to Improve Management of Major System Acquisitions*, which is reviewed in Chapter Three of this report. Other reports covering these specific types of facilities, individually or as a group, were not otherwise reviewed due to budget and time restrictions.

Chapters Three through Twenty are divided into five parts. The first part, “General Management Guidelines and Reports” (Chapters Three through Eight), discusses reports that address management issues that are germane to many if not all large scientific facilities. The next four parts discuss reports on specific types of facilities—“Reports on Astronomy and Astrophysics and the Hubble Space Telescope” (Chapters Nine through Eleven); “Reports on the Laser Interferometer Gravitational-Wave Observatory” (Chapter Twelve); “Reports on Neutron Scatterers” (Chapters Thirteen through Sixteen); and “Reports on Synchrotron Light Sources” (Chapters Seventeen through Twenty). The chapters within each part are presented chronologically by the publication date of the report under discussion, except when a report is a follow-up to a previous one, in which case they follow one after the other.