Managing the NIH Bethesda Campus Capital Assets for Success in a Highly Competitive Global Biomedical Research Environment

Committee on Assessing the Capital Needs of the National Institutes of Health

Board on Infrastructure and the Constructed Environment

Division on Engineering and Physical Sciences

A Consensus Report of

The National Academies of

SCIENCES · ENGINEERING · MEDICINE

THE NATIONAL ACADEMIES PRESS

Washington, DC

www.nap.edu

THE NATIONAL ACADEMIES PRESS **500 Fifth Street, NW** **Washington, DC 20001**

This activity was supported by Contract No. HHSN292201700014C. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

International Standard Book Number-13: 978-0-309-49436-6
International Standard Book Number-10: 0-309-49436-2
Digital Object Identifier: https://doi.org/10.17226/25483

Front cover: Aerial photograph of the NIH Clinical Center, 2014. Courtesy of the Office of NIH History and the Stetten Museum. *Back cover:* Aerial photograph of the NIH Bethesda Campus. Courtesy of the National Institutes of Health.

Additional copies of this publication are available for sale from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2019. *Managing the NIH Bethesda Campus Capital Assets for Success in a Highly Competitive Global Biomedical Research Environment.* Washington, DC: The National Academies Press. doi: https://doi.org/10.17226/25483.

The National Academies of

SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.nationalacademies.org**.

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

Consensus Study Reports published by the National Academies of Sciences, Engineering, and Medicine document the evidence-based consensus on the study's statement of task by an authoring committee of experts. Reports typically include findings, conclusions, and recommendations based on information gathered by the committee and the committee's deliberations. Each report has been subjected to a rigorous and independent peer-review process and it represents the position of the National Academies on the statement of task.

Proceedings published by the National Academies of Sciences, Engineering, and Medicine chronicle the presentations and discussions at a workshop, symposium, or other event convened by the National Academies. The statements and opinions contained in proceedings are those of the participants and are not endorsed by other participants, the planning committee, or the National Academies.

For information about other products and activities of the National Academies, please visit www.nationalacademies.org/about/whatwedo.

COMMITTEE ON ASSESSING THE CAPITAL NEEDS OF THE NATIONAL INSTITUTES OF HEALTH

KENNETH W. KIZER, NAM,[1] University of California, Davis, School of Medicine, *Chair*
EDWARD DENTON, University of California, Berkeley (retired)
DON EUGENE DETMER, NAM, University of Virginia, School of Medicine
LAURA FIDLER, AMC Strategies, LLC
G. EDWARD (Edd) GIBSON, JR., Arizona State University
SANJIV GOKHALE, Vanderbilt University
MICHAEL HARBER, St. Jude Children's Research Hospital
KERSTIN HILDEBRANDT-ABDIKARIM, Children's National Health System
DOUGLAS KINCAID, Applied Management Engineering, Inc.
THOMAS MITCHELL, FM3IS Associates, LLC
KIRK PAWLOWSKI, State of Washington Educational Service District 112
WILLIAM SEED, Jackson Health System
SARAH SLAUGHTER, NAE,[2] Built Environment Coalition
PHILIP TOBEY, SmithGroupJJR

Staff

GREG EYRING, Senior Program Officer
MARTIN OFFUTT, Senior Program Officer, *Study Director*
CAMERON OSKVIG, Director, Board on Infrastructure and the Constructed Environment
JOSEPH PALMER, Senior Program Assistant

---

[1] Member, National Academy of Medicine.
[2] Member, National Academy of Engineering.

BOARD ON INFRASTRUCTURE AND THE CONSTRUCTED ENVIRONMENT

[1] Through December 31, 2017.
[2] Through December 31, 2018.
[3] Member, National Academy of Engineering.
[4] Member, National Academy of Medicine.

Preface

For many decades, the National Institutes of Health (NIH) has produced a steady stream of cutting-edge advances in biomedical research and the health sciences. While these breakthrough discoveries garner news headlines, the laboratory facilities and other physical infrastructure that enable such scientific advances are rarely discussed. The evolving needs of biomedical research and clinical science place high demands on the buildings, laboratories, and utility and supporting services infrastructure. Without adequate infrastructure, neither NIH nor any scientific research entity would be able to accomplish its mission.

Taking an interest in this tension between the science and physical plant, the U.S. Congress, per the Consolidated Appropriations Act of 2017, requested that the National Academies of Sciences, Engineering, and Medicine "[p]repare a report that assesses the capital needs of NIH's main campus." Legislators envisaged the study's purpose as "to ensure the committee is informed of NIH's critical facility needs and inform future infrastructure budgets." The request focused on the main NIH campus located in Bethesda, Maryland.

The 310-acre Bethesda Campus houses the leadership of the 27 NIH institutes and centers, as well as a substantial portion of the Intramural Research Program (IRP). The latter is carried out by some 1,100 principal investigators and several thousand additional scientists in government-owned facilities. The operating funds for the IRP comprise about one-tenth of the NIH budget. In addition to IRP funding, funds have been appropriated specifically for buildings and facilities, which are utilized mainly for the Bethesda Campus.

The committee tasked with this study spent substantial amounts of time on the Bethesda Campus, looking firsthand at the biomedical and clinical research facilities and other infrastructure (e.g., the utilities that provide essential energy and sanitation services to the campus) providing research support. The committee augmented this with a detailed review of written records, attempting to understand not only planning and operations but also, to the extent possible, how appropriations related to the operating budgets of the Bethesda Campus and how scientific funds tallied against spending on specific buildings.

The committee undertook its work with an eye toward how the capital assets on the Bethesda Campus were supporting the NIH mission today, as well as how they might do so into the future. The NIH Office of Research Facilities arranged multiple site visits that allowed the committee to see facilities that supported specialized laboratory spaces supporting newer avenues of scientific inquiry such as bioinformatics and high-speed computing—sciences that, generally speaking, are newer than the NIH buildings that house them. The committee also spent one full day in an interdisciplinary space—the Porter Neuroscience Research Center, a building delivered in two phases in 2004 and 2014—that represented a move away from the traditional approach to facilities on the Bethesda Campus.

Many individuals volunteered significant time and effort to address and educate the committee during its public information sessions. Francis Collins (NAS/NAM), director of NIH, held substantive discussions with the committee, as did Michael Gottesman, M.D. (NAS/NAM), deputy director for intramural research, and Alfred C. Johnson, Ph.D., deputy director for management. Paul Sieving, M.D. (NAM), director of the National Eye Institute and chair of the NIH Facilities Working Group, acted as the liaison to the committee from the institutes and centers. James Gilman, M.D., CEO of the Clinical Center, personally led the committee on tours of that center and provided informative briefings. Helping to pull it all together was Dan Wheeland, P.E., the director of the Office of Research Facilities. Numerous other individuals, listed in Appendix C, provided valuable insights as well. To all these individuals and others not named here, the committee extends its heartfelt thanks and appreciation.

The committee considers NIH to be a critical national resource that is integral to the nation's health, well-being, and national security. We hope the Congress will embrace the committee's findings, as detailed in this report, and provide NIH with the funding and support needed for it to fulfill its mission and continue its unparalleled legacy.

Kenneth W. Kizer, M.D., M.P.H., *Chair*
Committee on Assessing the Capital Needs
of the National Institutes of Health

Acknowledgment of Reviewers

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

Norman Augustine, NAS[1]/NAE,[2] Lockheed Martin Corporation (retired),
Richard Berman, NAM,[3] University of South Florida,
Thomas Budinger, NAM/NAE, University of California, Berkeley,
Steven Crane, Crane Strategies,
Stephen Maiorisi, Harvard Medical School,
Chris Poland, NAE, Chris Poland, Consulting Engineering,
Gerald Rubin, NAS/NAM, Howard Hughes Medical Institute, and
Elias Zerhouni, NAM/NAE.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by Martin Philbert, NAM, University of Michigan. He was responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

---

[1] Member, National Academy of Sciences.
[2] Member, National Academy of Engineering.
[3] Member, National Academy of Medicine.

Contents

Summary

INTRODUCTION

The United States has long led the world in biomedical research, and the National Institutes of Health (NIH) has been the unparalleled leader in this regard. In addition to funding investigators across the country through its Extramural Research Program, NIH has also carried out a highly productive Intramural Research Program (IRP) consisting of basic and applied biomedical and health-related research. The IRP has been a magnet for attracting highly talented scientists and trainees from across the nation and around the globe, providing the foundation for and being a catalyst to the nation's preeminence in biomedical research. However, the ability of the IRP to continue in this vein has been challenged in recent years by a number of dynamics, including especially the aging and deteriorating condition of many of the buildings and facilities at NIH's Bethesda Campus.

The buildings and facilities at NIH's Bethesda Campus house the majority of the IRP and comprise a multi-billion-dollar public investment. The Bethesda Campus includes numerous laboratories; a 200-bed research hospital with a broad array of outpatient clinics; administrative space; and facilities providing research support services, energy and transportation services, and other utilities. The staff of more than 20,000, including some 1,100 principal investigators, depends on these buildings and facilities and capital infrastructure to support the highly sophisticated and often groundbreaking research conducted on the campus.

The lagging condition of the Bethesda Campus buildings and facilities received congressional attention in the Consolidated Appropriations Act of 2017, in which legislators noted that "Over time, only the most essential maintenance and repairs for health and safety have been addressed, leaving an increasing backlog of projects requiring attention."[1] The Act directed NIH to "enter into a contract with the National Research

---

[1] Pp. 111-112 of Senate Report 114-274: Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriation Bill, 2017 (Division H of the Consolidated Appropriations Act).

Council, Division on Engineering and Physical Sciences, to prepare a report that assesses the capital needs of NIH's main campus."[2]—that is, the needs of the Bethesda Campus.
Subsequently, NIH and the National Academies developed a contract with a statement of work as follows:

> At the request of the Office of Research Facilities Development and Operations, National Institutes of Health, the National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee to: (1) identify facilities in greatest need of repair or those most impacting mission implementation; (2) assess the rationale and composition of projects to bring the NIH main campus facilities up to current standards or acceptable operational performance which meet mission objectives; (3) evaluate at a high level the completeness, accuracy, and relevance of cost estimates (already developed by/for NIH) for proposed capital projects; and (4) identify potential factors and approaches that the NIH should consider in developing a comprehensive capital strategy for its main campus portfolio of facilities. It is desired that the study identify approaches based on five (5), ten (10), and twenty (20) year prioritization outlook.
>
> In addition, to better inform sustainment of NIH's main campus and capital planning, the study committee shall review comparable available facility condition methodologies and metrics of other federal agencies at an overall portfolio level, and provide recommendations in determining the minimum levels of funding required to sustain NIH's assets at an overall portfolio level.

To conduct the study, in late 2017 the National Academies established the Committee on Assessing the Capital Needs of the National Institutes of Health. During its deliberations, the committee spent substantial amounts of time at the Bethesda Campus. This included inspecting the Clinical Center, the Porter Neuroscience Research Center, the dedicated animal vivarium (i.e., the Building 14/28 complex), the infrastructure core (including the combined utility plant, industrial water storage, and thermal energy storage tanks), and specialized laboratory spaces (including bioinformatics). The committee interacted with multiple directors of institutes and centers (ICs), the director of the Office of Research Facilities, and other NIH officials, as well as officials from other federal agencies with responsibility for asset management. The director of NIH, the deputy director for management, and the deputy director for intramural research all spent time meeting with the committee. This report describes the findings and recommendations of the committee.

NIH BETHESDA CAMPUS: FACILITIES AND ACTIVITIES

The 310-acre Bethesda Campus of the National Institutes of Health includes a large intramural research program nested within an administrative structure that offers central oversight over all NIH activities—intramural and extramural. The intramural programs are located on the Bethesda Campus and adjacent sites (with a few exceptions), whereas the extramural programs are performed by academic and other research institutions across the nation.

The history and culture of NIH, and especially the Bethesda Campus, have a material bearing on the comprehensive capital strategy for the campus portfolio of facilities. Extraordinary advances in the treatment of common and rare diseases have been made at NIH, and its scientists continue to expand the boundaries of knowledge about human biology and disease. Through its intramural and extramural research programs, young investigators are schooled in the disciplines of performing research and reporting research findings. As the information technology revolution has taken hold over the past 50 years, NIH scientists and researchers have brought the world's health-related literature into the hands of researchers, practitioners, and citizens worldwide. Overall, NIH is a critical national resource that is essential to medical science and to national security relating to health.

---

[2] The NIH Office of Research Facilities and the National Academy of Sciences subsequently entered into a contract on September 30, 2017.

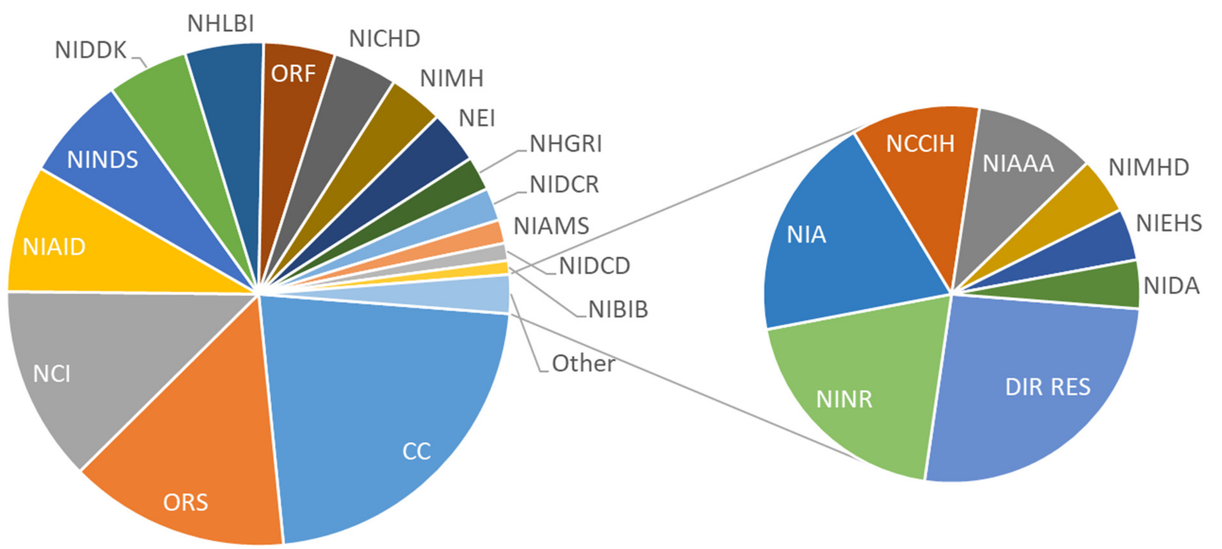


FIGURE S.1 The National Institutes of Health (NIH) Bethesda Campus assigned space by institute and center (excluding units with no space assigned—falling in the categories of wet laboratory, clinical research, or vivarium). NOTE: Acronyms defined in Appendix K. SOURCE: Data from NIH.

The structure and organization of NIH, in comparison to most other biomedical research organizations, is driven by government funding, political as well as policy support (particularly from the legislative branch), and strong external public advocacy groups. The NIH director oversees a confederation of 27 disparate ICs with vastly different space requirements (see Figure S.1), rather than a centrally controlled organization. The missions of the institutes themselves, in colloquial language, mostly relate to parts of the body and health conditions such as eye and heart health, cancer, aging, allergies and infectious diseases, and neurological conditions. Complementing such institutes is the work of the Clinical Center, which links patient care with basic research discoveries and programs for the study of undiagnosed diseases and rare diseases and conditions. In addition, various core support services are provided on campus to the ICs. For example, the Division of Veterinary Resources manages 11 buildings totaling 300,000 gross square feet of animal housing and laboratory space, as well as 7 buildings totaling 150,000 gross square feet of animal housing space at the 513-acre NIH animal center in Poolesville, Maryland. The DVR provides housing for approximately 100,000 animals. The core support services recently became a focus of the IRP, which, in 2017, adopted the NIH-wide Collaborative Research Exchange (CREx)—a marketplace connecting IRP investigators with more than 110 IRP core capabilities and external vendors.

The committee believes that the peculiarities of the NIH organizational structure and the nature of its funding streams present a number of unique challenges in managing the buildings and other capital assets on the Bethesda Campus, as discussed below. A little more than one-tenth of the total NIH budget supports the Bethesda Campus, although comparatively, the budgets for research facilities and related infrastructure at the NIH Bethesda Campus have not kept pace with the capital asset investments of a number of similarly focused enterprises that now compete with NIH in biomedical research.

Today, biomedical research facilities are supported by architectural and engineering solutions that prioritize flexible and adaptive space, shared facilities, and multiple, diverse, and often social spaces in which teams of differing sizes and composition can pursue investigations. Public and private organizations are also considering alternative capital asset management approaches for their research facilities to avoid accelerating obsolescence and "stranded space capital assets," identifying strategies that will maximize the deployment of increasingly scarce capital financial resources, and most importantly, remain competitive in retaining and recruiting current and future scientists to sustain impactful discovery research.

In recent years, NIH has begun integration of the IC's intramural resources and programs to foster collaboration. Some recent developments in this regard were evident during the committee's visits to the campus. For example, the John Edward Porter Neuroscience Research Center, which opened in 2004 (with a second phase opening in 2014), is a state-of-the-art 500,000-square-foot energy-efficient life science facility that brought together under one roof 800 scientists and 85 research labs from 10 ICs. Other shared facilities include a peptide sequencing facility, a magnetic resonance imaging suite, and a light imaging facility. Similarly, NIH's data science and high-performance computing infrastructure has been greatly expanded in the past 5 years in response to the increasing data infrastructure needs of IRP investigators. Notwithstanding these important developments, the committee felt that considerably more could be done at the Bethesda Campus to promote a more flexible, collaborative, and integrated research milieu.

CURRENT CONDITIONS

The buildings and facilities at the NIH Bethesda Campus are in need of significant improvement and upgrading to sustain their current mission and ongoing functionality. The 12 million facility square feet have an average Condition Index of 83.3, which is considered poor.[3] Seventy-two percent of the facilities are more than 20 years old, and much of the supporting infrastructure is significantly older. The Backlog of Maintenance and Repair (BMAR) as tracked by NIH and briefed to the committee is $1.3 billion and growing rapidly due to insufficient annual funds to keep pace with needs. These needs include upgrading power and water distribution systems, roof repair and leak mitigation, road and parking improvements, and enhancing safety and security infrastructure.

Over the past 20 years, a number of individual facilities have been funded by congressional appropriations for defined uses, but funding has not adequately addressed the overall BMAR needs. The congressionally controlled Buildings and Facilities (B&F) account, requested in the President's budget and appropriated by Congress, has been stagnant at or slightly above $100 million for approximately 15 years (Figure S.2). This level of spending has not been sufficient to address the overall campus needs. The fiscal year (FY) 2019 B&F account increase to $200 million, kept level-funded for FY 2020, is not sufficient to match the current annual growth in BMAR and is wholly inadequate to reduce the previous years' backlog.

The committee recommends a total of $1.3 billion in new funding to address the Bethesda Campus's needs to upgrade its buildings and facilities. The committee believes that this new funding should be allocated in two tranches. An initial tranche in the range of $700 million should be made available as soon as possible for the purpose of replacing or improving infrastructure serving current and future facilities and their associated science (Recommendation 4.1). A second tranche of some $600 million should be made available in accordance with further assessment of various facilities within the context of an updated overall campus Master Plan (Recommendations 4.1, 5.1, and 5.2). The committee further recommends policy changes to the B&F funds to protect a sustaining level of funds (Recommendation 4.2) to focus on future BMAR reduction and to create a recurring annual plan to identify specifically how that reduction will occur (Recommendation 4.3).

[3] Condition Index is defined as the difference between the replacement value of an asset and the BMAR, divided by the replacement value.

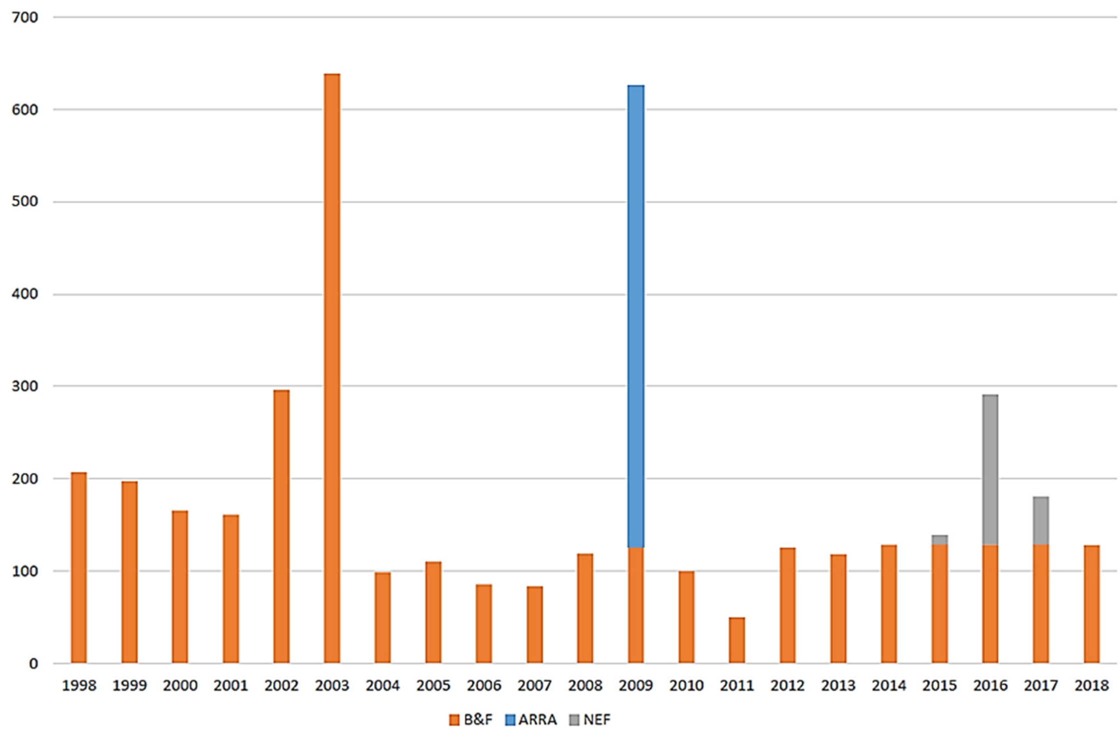


FIGURE S.2 National Institutes of Health (NIH) funding levels for facilities (1988-2018) in millions of dollars. Includes the appropriated Buildings and Facilities (B&F) account, the American Recovery and Reinvestment Act (ARRA) of 2009, and funds made available from the Department of Health and Human Services (HHS) through the nonrecurring expense funds (NEF).

Recommendation 4.1: The currently identified $1.3 billion in the Backlog of Maintenance and Repair (BMAR) should be funded in two tranches. First, fund the entire long-term infrastructure improvements totaling approximately $700 million over a specific time period (e.g., 5 years) so that a comprehensive plan can be undertaken to support the ongoing research activities and begin preparation and support for any future Master Plan improvements. (The full title is "2013 Comprehensive Master Plan—Bethesda Campus.") Second, the remaining $600 million needs to be considered for each building in light of its future as defined in the approved Master Plan.

Recommendation 4.2: The Buildings and Facilities account, or other account, should have an annual dedicated investment amount—determined by considering the amount of Backlog of Maintenance and Repair (BMAR), building condition index, and historical levels of spending—for reduction or elimination of BMAR that can be used only for this purpose.

Recommendation 4.3: NIH should adopt and implement a Deferred Maintenance and Repair program focused on building and utility system condition data that will minimize or eliminate specific failures that are disruptive to mission accomplishment and to reduce Backlog of Maintenance and Repair while attaining the building Condition Index (CI) target stated in the Master Plan. The methods that the committee recommends for capital planning prioritization—that is, incorporating CI and mission dependency—can be adapted for this purpose.

CURRENT CAPITAL ASSET MANAGEMENT AT NIH

Asset management in any large research campus environment is a challenging process; however, the challenge at the NIH Bethesda Campus is more than most, for a number of reasons. The B&F account, noted above, has numerous interests vying for its use, ranging from system repair, to adapting space for scientific research equipment, to office reconfiguration, to utility and life safety updates. There is no funding dedicated to retiring BMAR. NIH's organizational structure of 27 individually funded ICs makes achieving consensus on the future and capital assets planning extremely difficult, especially as it relates to common-use resources such as facilities in the Clinical Center, the Building 12 Data Center, and the dedicated animal vivarium (i.e., Building 14/28 complex) and vivariums co-located in research buildings.

The variety of funding streams that NIH's internal Facilities Working Group (FWG) must pursue complicates the prioritization process. Large projects are queued and prioritized through a 1,000-point system and then advanced to a point of submission readiness to apply biannually for nonrecurring expense funds, repurposed and redirected at the Department of Health and Human Services-level, or to solicit congressional funding. Monies from the B&F account are used to advance these projects rather than to address sustaining current operational needs. It was not obvious to the committee how this process considers the balance of the overall campus needs when prioritizing funding requests. Understandably, it is difficult to get financial donors interested in funding repairs and utility upgrades over a new high-profile building.

The Bethesda Campus utilizes an annual building and utility system assessment process that identifies a Condition Index for each building. However, there seems to be missing in this process an indication of functional value. The committee has identified a number of federal research programs (e.g., MIT Lincoln Laboratory, Naval Research Laboratory, Johns Hopkins University Applied Physics Laboratory, and U.S. Army MEDCOM) that have utilized this concept of functional value to better inform their needs and to help make the often difficult decisions that are required in a funding-constrained environment. Disruptions of work at the NIH Bethesda Campus occur not infrequently due to building componency failure and deterioration. The committee recommends that functional value be included as a much more highly rated variable in the decision making system (Recommendation 5.1). It is recommended that the FWG review and learn about this process from peers at the above-noted or similar organizations (Recommendation 5.3). This limitation of NIH's current capital asset management practices was repeatedly noted by the committee. To remedy this, the committee recommends wider engagement of NIH with planners and practitioners in other organizations. These upgrades and repairs to existing buildings/systems should be considered alongside the Master Plan needs for new facilities (Recommendation 5.2). With the consideration of the above inclusion into the scoring system, the committee recommends that the assessments be reconsidered to determine if the prioritization remains the same (Recommendation 5.1).

Recommendation 5.1: NIH should revise its Building and Facilities (B&F) prioritization model so that a significant portion of the 1,000-point scoring system (no less than one-third of the total points) includes the Condition Index and Mission Dependency Index as objective parameters. Using this revised model, NIH should reassess all current projects in the 5-year B&F plan. The balance of the $1.3 billion of funding (i.e., $600 million) should be prioritized based on this assessment. This assessment could also be used to determine the annual required funding set aside.

Recommendation 5.2: NIH should utilize the changes in the Building and Facilities prioritization model to complete an analysis of projects to modify or replace Building 12, the Building 14/28 complex, and various active or planned projects to renovate or replace portions of Building 10 occupied by the Clinical Center. If the analysis supports a high priority for these projects, then NIH should continue with efforts to move forward as quickly as possible with these projects.

Recommendation 5.3: NIH should seek out the federal agencies referenced in this report, along with other similar agencies, to determine if there are best practices that it can utilize. NIH should

consider regular (e.g., quarterly) engagements with these agencies to review its Capital Asset Management Program, as well as how the engagement of key individuals from the institutes and centers (at all levels of the organization who are impacted by the program) and the private sector could enhance the success of NIH projects.

NIH APPROACH TO MANAGING ITS BETHESDA CAMPUS BUILDINGS AND FACILITIES

In 2015, NIH developed a comprehensive Strategic Plan designed to synchronize research program priorities and support forward-thinking decisions across the 27 ICs. The document, *NIH-Wide Strategic Plan Fiscal Years 2016-2020: Turning Discovery into Health*, establishes four objectives: (1) advance opportunities in biomedical research; (2) foster innovations by setting NIH priorities; (3) enhance scientific stewardship through recruitment, partnership, and management; and (4) excel as a federal science agency by managing for results (NIH, 2015c). However, the *NIH-Wide Strategic Plan* did not establish enterprise-wide priorities, and this committee is not aware of any detailed implementation plans for the identified strategic objectives, particularly the ways in which the research strategy depends upon specific building or infrastructure facilities, space utilization policies, or capital investment strategies. As outlined in the document *Long-Term Intramural Research Program Planning Working Group Report* (NIH ACD, 2014),[4] the IRP has an important role to support the full integration of the NIH biomedical research effort. This integration role may require changes in the IRP structure and culture to support team science (including local, national, and international collaborations), as well as state-of-the-art research facilities, with an emphasis on facility and research infrastructure integration and optimization.

A further NIH-authored document, *2013 Comprehensive Master Plan—Bethesda Campus* (NIH ORF, 2013), or "Master Plan," has four implementation strategies that could be paraphrased as follows: (1) advance NIH's Strategic Research Initiatives; (2) replace aging capital facility assets; (3) reduce NIH's leased space; and (4) resolve regional traffic congestion. In particular, the Master Plan emphasizes the renovation of outdated research facilities and the construction of new administrative space to accommodate employees residing in leased space on campus. It also proposes to organize the Bethesda Campus into five research clusters to facilitate collaboration and create opportunities for development of multi-institutional centers and address other trends such as computational biology. This committee was unable to find any formal process that establishes an integrated proactive management practice that explicitly links the NIH-wide research strategies to facility management and planning efforts—a process that, if implemented, could facilitate timely updates to accommodate rapidly changing research directions, processes, and methods.

The NIH Office of Research Facilities (ORF) manages the current capital investment planning. The ORF processes for repair and improvement include identifying and prioritizing specific projects annually, perhaps as often as quarterly, based on regular meetings among ORF maintenance and operations subject matter experts and other technical staff. The NIH ORF also manages capital cost models for projects on the Bethesda Campus in response to specific requests from the 27 ICs throughout the year. Based on project cost materials provided, the committee finds that the current cost estimates are generally consistent with information required of NIH from the *U.S. Department of Health and Human Services Facilities Program Manual (Volumes I and II)* guidelines and uses consistent general capital cost categories. However, inconsistent metrics appear to exist within key NIH Capital Cost Template cost model line items. These inconsistencies do not appear to be based on typical variables, including geographic factors (e.g., seasonal or [clinical or research] operations schedule requirements or labor conditions impacts), construction cost scale of a project, project duration due to construction or regulatory entitlement processes, capital cost escalation factors, project complexity, construction phasing, acquisition of major equipment components, or other variables among individual capital projects.

The committee believes that NIH would benefit significantly from an explicit integration of its research Strategic Plan with its capital facility asset management plan, with clear prioritization relating the long-

[4] Authored by a working group of the statutory NIH director's Advisory Committee.

term research strategy to the 20-year campus Master Plan. This integration may also include a rigorous and detailed 10-year deferred maintenance backlog reduction plan integrated within a 10-year major capital improvement plan. Such plans would require annual redevelopment and review and adoption at the highest levels of NIH (Recommendation 6.1). Both the NIH-wide Strategic (Research) Plan and the campus Master Plan, discussed above, emphasize the importance of enhancing interactions and collaboration among IRP research personnel and partners through shared space and facilities, and the need for flexible and adaptable facilities to accommodate these collaborations and rapidly changing research program needs.

As noted in the April 2016 report *Reducing Risk and Promoting Patient Safety for NIH Intramural Clinical Research: The Clinical Center Working Group Report to the Advisory Committee to the Director*, there was "no independent entity to verify that engineering controls for high-risk facilities meet appropriate regulations or standards prior to or after construction." (NIH ACD, 2016) The committee believes that NIH would be well served by establishing a formal third-party (external) peer review of the NIH ORF planning documents (including cost models) from the very earliest stages of the capital planning process to completion and reassessment of the capital facility asset portfolio (Recommendation 6.2). Here again, the committee sees value in wider engagement of NIH with planners and practitioners in other organizations (see also Recommendation 5.3).

Recommendation 6.1: NIH should integrate its research strategic plan with its capital facility asset management plans, with explicit prioritization aimed at relating the long-term research strategy to the long-term campus Master Plan. This integration should include a rigorous and detailed 10-year plan for reduction of its Backlog of Maintenance and Repair that is embedded within the institution's major capital improvement plan (currently the Buildings and Facilities/Nonrecurring Expenses Fund-funded 5-year plan). These plans should undergo annual review, redevelopment as needed based on review, and adoption at the highest levels of NIH.

Recommendation 6.2: NIH should establish a formal external interdisciplinary peer review panel to provide ongoing review of NIH capital assets, the annual project plan, the 5-year plan, the master plan, and the integrated research strategic plan and master plan, including enhancing interactions and collaboration among Intramural Research Program research personnel and partners.

Recommendation 6.3: NIH should establish processes and a system that ensure third-party, expert peer review of all adopted Office of Research Facilities preplanning programs of requirements and total project capital cost models.

FUTURE NIH APPROACH TO PLANNING

NIH is one of many government scientific research agencies that must strategically align the availability of facilities with its real estate portfolio to achieve organizational goals, while contending with constrained budgets and rising facility operating costs and responding to technological and socioeconomic drivers and federally mandated compliance requirements. Facilities asset management has been defined by the National Research Council as "a systematic process for maintaining, upgrading, and operating physical assets cost effectively." It combines engineering principles with sound business practices and economic theory and provides tools to facilitate an organized, logical approach to decision making.

The committee benchmarked NIH's capital asset management against a handful of federal agencies with scientific research missions. Overall, capital facilities planning leadership and management continues to be led by the research scientist community and, with few exceptions (e.g., U.S. Department of Agriculture Agricultural Research Service), has not collaborated with the capital facilities financial and technical staff (e.g., engineers, architects, planners) as peers, but instead views them as "staff support." In the process of benchmarking, the committee also identified a need for greater engagement and sharing of information with these other agencies (see Recommendation 7.3, below, and also Recommendations 5.3 and 6.2, above).

The committee also considered recent trends in capital asset management. Research institutions are utilizing multiple and innovative financial instruments, including debt capacity analyses, philanthropy, increasing the relocation of operating budget resources to capital budgets to provide additional cost participation from noncentral institutional funds, use of shared core facilities, and outsourcing core facilities (including animal care facilities), lease and buy back, and other capital development strategies that do not use scarce institutional capital resources. Another capital development strategy utilizes public/private capital or private sector-only financial funding sources for parking structures, dry research laboratory, animal care facilities, and administrative office, food service, residential housing, utility infrastructure, and other capital projects (including public safety, day care, and other "amenities") associated with the biomedical research enterprise.

Due to the accelerating competition for capital resources in both the private and public sectors of the national and global research enterprise, the role of capital facilities financial planning is recognized as a critical component requiring subject matter expertise within central administrative leadership to support institutional financial sustainability. In addition, more comprehensive capital facilities plans and capital project reviews are required to achieve a more highly integrated capital and scientific program decision making model that is more quantitative, objective, and able to withstand external peer review.

Recommendation 7.1: NIH should study the non-NIH federal research programs described in this report, among others, and incorporate or adopt, where appropriate, functionally similar assessment, prioritization, and funding strategies for the purpose of better meeting facilities and infrastructure investment needs.

Recommendation 7.2: NIH should implement a capital facilities planning governance structure, functionally similar to that utilized by other scientific agencies noted in this report, aimed at facilitating an integrated, transparent, and inclusive capital asset planning decision making process. This governance structure should facilitate tracking the agency's progress toward achieving its strategic and programmatic objectives.

Recommendation 7.3: NIH should convene an annual capital facilities planning workshop or similar forum with other federal agencies and academic research institutions for the purpose of assessing NIH capital asset management program processes and identifying improvements, including the ongoing development of a capital financial resource sustainability plan. The proceedings of this workshop and any recommendations should be distributed to the institutes and centers and central administrative leaders, among others, and be used to inform Intramural Research Program budget development. There should be broad participation in the workshop, including by principal investigators, junior faculty, and research laboratory staff; capital and operating budget staff; information technology leaders; capital planning staff; campus infrastructure operations staff and maintenance leaders; and representatives from other federal agencies and academic research institutions.

Recommendation 7.4: To verify the presence of subject-matter expertise within its core administrative leadership, NIH should review and consider whether its organizational structure ensures that its Bethesda Campus scientific research and capital assets management strategies and plans are aligned. In doing so, NIH should consider how other federal agencies with research missions have accomplished this end by assigning a senior organizational leader with such responsibilities and empowering that person with commensurate authority.

THE EVOLVING GLOBAL BIOMEDICAL RESEARCH ENVIRONMENT: IMPLICATIONS FOR NIH AND ITS CAPITAL ASSETS

Significant changes have occurred over the past several decades in how biomedical research is conducted and who is conducting it. The dominant paradigms of the past have been replaced with a new overarching paradigm for research that is broader and is "biopsychosociotechnical" rather than simply "biomedical." This paradigm recognizes that positive impacts from research on human health proceed from understanding and successfully impacting all relevant biological, psychological, sociological, and technological dimensions relating to the condition. The concept of "team science," defined as a scientific collaboration by more than one individual in an interdependent fashion, has evolved because of the increasing need to bring experts from multiple disciplines together to address complex problems. Having flexible and adaptable contemporary biomedical research space is essential to accommodate the current and future needs of multidisciplinary research teams.

Recommendation 8.1: NIH should explicitly prioritize the initiatives specified within the NIH-wide Strategic (Research) Plan and the 2013 Bethesda Campus Master Plan (or its successor), which emphasize the importance of enhancing interactions and collaboration among Intramural Research Program research personnel and partners through shared space and facilities, and the need for flexible and adaptable facilities to accommodate such collaborations and rapidly changing research program needs. This should apply to existing facilities as well as new facilities, and through further enhancement of key strategic shared core assets such as Biowulf and the Clinical Center.

CONCLUSION

The NIH Bethesda Campus has supported best-in-class biomedical and clinical research for decades. The ability of the campus's IRP to continue in this vein has been substantially challenged in recent years by the deteriorating condition of many of the NIH Bethesda Campus buildings and facilities. To address this growing problem, NIH will need a substantial infusion of funding to bring the condition of these buildings and facilities to an acceptable level. In the future, it will need to spend available monies so as to avoid yet another buildup of deferred maintenance and, in its planning process, give more weight to functional value of the facilities that are the beneficiaries of proposed improvements and build-outs. NIH's stewardship of its buildings and facilities has proven flexible and adaptable, and, with sufficient resources and improved asset management practices, it should be able to meet the evolving needs of its biomedical and clinical science enterprise.

1

Introduction

ORIGIN OF STUDY

In its conference report,[1] the Consolidated Appropriations Act of 2017 directed the National Institutes of Health (NIH) to enter into a contract with the National Research Council's[2] Division on Engineering and Physical Sciences to conduct a study of the capital asset needs of the NIH Bethesda Campus. Legislators prefaced this request with the note that "The committee understands that federal agencies such as NIH need to maintain and upgrade parts of their physical infrastructure every year. The NIH facilities budget has been relatively flat since 2009. Over time, only the most essential maintenance and repairs for health and safety have been addressed, leaving an increasing backlog of projects requiring attention." Legislators envisaged the study's purpose as "to ensure the committee is informed of NIH's critical facility needs and inform future infrastructure budgets."

The primary tasks for the study as described by Congress were to provide the following:

> Prepare a report that assesses the capital needs of NIH's main campus. The report should identify facilities in greatest need of repair, describe the work needed to bring them up to current standards, and include cost estimates for each project. The Committee directs NIH to provide the report with its recommendations to the House and Senate Committees on Appropriations no later than 1 year from the date of the contract agreement on the statement of work between NIH and the National Research Council.[3]

The NIH Office of Research Facilities and the National Academies of Sciences, Engineering, and Medicine entered into a contract on September 30, 2017. The National Academies established the Committee on Assessing the Capital Needs of the National Institutes of Health, composed of diverse experts

---

[1] Senate Report 114-274: Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriation Bill, 2017 (Division H of the Consolidated Appropriations Act), pp. 111-112.

[2] Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council are used in a historical context identifying programs prior to July 1.

[3] Senate Report 114-274, p. 112.

in the fields of project management, civil engineering, major facilities and campus management, government administration, and medical sciences. Committee member biographical information is provided in Appendix B.

CHARGE TO THE COMMITTEE

Per the contract, the committee is charged with the following:

> At the request of the Office of Research Facilities Development and Operations, National Institutes of Health, the National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee to: (1) identify facilities in greatest need of repair or those most impacting mission implementation; (2) assess the rationale and composition of projects to bring the NIH main campus facilities up to current standards or acceptable operational performance which meet mission objectives; (3) evaluate at a high level the completeness, accuracy, and relevance of cost estimates (already developed by/for NIH) for proposed capital projects; and (4) identify potential factors and approaches that the NIH should consider in developing a comprehensive capital strategy for its main campus portfolio of facilities. It is desired that the study identify approaches based on five (5), ten (10), and twenty (20) year prioritization outlook.
>
> In addition, to better inform sustainment of NIH's main campus and capital planning, the study committee shall review comparable available facility condition methodologies and metrics of other federal agencies at an overall portfolio level, and provide recommendations in determining the minimum levels of funding required to sustain NIH's assets at an overall portfolio level.

COMMITTEE'S APPROACH TO THE STATEMENT OF TASK

While conducting this study, the committee members relied on their own expertise, information from publications they judged to be of high quality, and many interactions with officials at NIH, including directors of institutes and centers and the director of the Office of Research Facilities as well as officials from other federal agencies with responsibility for asset management (Appendix C). The director of NIH, the deputy director for management, and the deputy director for intramural research all spent time meeting with the committee.

The committee spent substantial amounts of time on the NIH Bethesda Campus, including inspecting the Clinical Center, the Porter Neuroscience Research Center, the animal vivarium (i.e., the Building 14/28 complex), the infrastructure core (combined utility plant, industrial water storage, and thermal energy storage tanks), and specialized laboratory spaces, including bioinformatics. The committee also toured the 130 acres that comprise the built environment of the 310-acre campus.

STRUCTURE OF THIS REPORT

The statement of task is addressed by the chapters as outlined in Table 1.1. To set the context for the preceding, Chapter 2 of this report describes the new and evolving biomedical research ecosystem and its implications for biomedical and health-related enterprises, including the NIH Bethesda Campus—described in more detail in Chapter 3—and especially for the physical built environment and infrastructure in which research is being conducted. Insofar as the built environment is costly and expected to be useable for many years or decades, it must be designed and constructed to be flexible and highly adaptable to meet changing scientific needs and purposes.

TABLE 1.1 How the Statement of Task Is Addressed in This Report

Element of Statement of Task	Chapter(s) Addressing the Element
(1) Identify facilities in greatest need of repair or those most impacting mission implementation;	Chapter 4
(2) Assess the rationale and composition of projects to bring the NIH main campus facilities up to current standards or acceptable operational performance which meet mission objectives;	Chapter 5 and Chapter 6
(3) Evaluate at a high level the completeness, accuracy, and relevance of cost estimates (already developed by/for NIH) for proposed capital projects;	Chapter 6
(4) Identify potential factors and approaches that NIH should consider in developing a comprehensive capital strategy for its main campus portfolio of facilities. It is desired that the study identify approaches based on five (5)-, ten (10)-, and twenty (20)-year prioritization outlook.	Chapter 7 and Chapter 8
In addition, to better inform sustainment of NIH's main campus and capital planning, the study committee shall review comparable available facility condition methodologies and metrics of other federal agencies at an overall portfolio level, and provide recommendations in determining the minimum levels of funding required to sustain NIH's assets at an overall portfolio level.	Chapter 7

2

Global and National Biomedical Research Environment

BIOMEDICAL RESEARCH ENVIRONMENT AND KEY EMERGENT TRENDS

America's scientists have been for decades among the world leaders in publishing high-impact biomedical research discoveries. The United States, and especially the National Institutes of Health (NIH), has been a magnet for attracting talented scientists and trainees from around the globe. However, U.S. research and development (R&D) expenditures have relatively stagnated in recent decades, while other countries—especially in Asia—have markedly expanded their investments in R&D and infrastructure. As a result, America's biomedical leadership position is increasingly vulnerable (Guarino et al., 2018; Lafrance, 2017; Conte et al., 2017; Moses et al., 2015; Huang et al., 2016; Sargent, 2018).

The American research enterprise is a complex interconnected system that is directly and indirectly affected by national and global changes. An array of components is becoming essential for world-class interdisciplinary research in all areas of science. This includes a talented interconnected workforce, adequate and dependable financial resources, and adaptable state-of-the-art facilities having appropriate technology as an infrastructure for research (Figure 2.1) (NASEM, 2018b; NRC, 2014).

To address the time horizon of 20 years in the committee's charge, this chapter summarizes the factors likely to dominate the research environment for the next two decades. Some dimensions are more widely recognized and have supporting references, while others relate to the individual and collective experience and judgment of committee members. These factors are summarized in Table 2.1.This changing landscape is the contemporary and emerging terrain in which the NIH Bethesda Campus must successfully compete if it is to maintain a global leadership role and to serve as an essential distinctive national security asset.

These trends within the new interdependent biomedical research ecosystem have critical implications for all biomedical and health-related enterprises, including the NIH Bethesda Campus, and especially for the physical built environment and infrastructure in which research is being conducted. Insofar as the built environment is costly and expected to be usable for many years or decades, it must be designed and constructed to be flexible and highly adaptable to meet changing scientific needs and purposes.

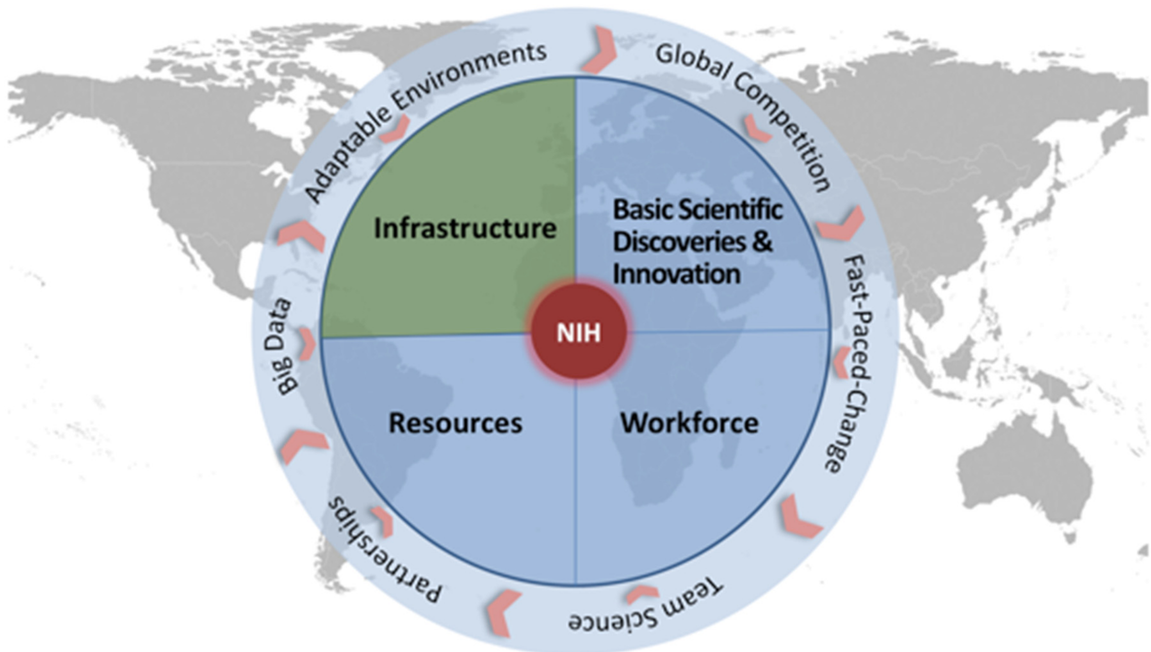


FIGURE 2.1 Global biomedical ecosystem.

TABLE 2.1 The Changing Biomedical/Health Global Research Environment

Past	Current and Emerging
United States and NIH Bethesda Campus domination of global biomedical research	Exceptional biomedical research capacity existing in multiple locations, and global competition for talent and discovery
Consistent and measured pace of transformation	Rapidly accelerating pace of transformative change
Traditional discrete disciplines	Transdisciplinary/multidisciplinary
Funding directed at the discovery of basic biological processes to advance knowledge	Increasing focus on commercialization and application of discoveries and maintenance of intellectual property
Expected deliverable: discovery	Expected deliverable: cures or disease prevention/avoidance
Focus on biomedical	Focus on bio-psycho-social-technological
Independent and siloed data repositories	Informatics, “big data,” data science, data analytics
Abundance of young talent having defined career tracks	Global competition for young talent having nonlinear and “fluid” career tracks
Research conducted by individual teams	Research conducted by multi- and interdisciplinary research teams collaborating on the local, national, and international level in a team science environment
Top-down management	Complex adaptive systems approach
Buildings designed around traditional disciplinary and departmental structures; designated “wet lab” space and offices assigned to principal investigators and their teams	“Social buildings” to enable interdisciplinary team-based research, with space that is flexible and adaptable to support present needs and capable of rapidly accommodating future demands

The dominant paradigms for the past environment for research include (1) biomedical research focus, (2) discovery of underlying structures and processes of biology and materials, (3) distinctive traditional research disciplines, and (4) an abundant talent pool seeking well-defined and supportive career trajectories. The NIH Bethesda Campus has served as a dominant force in this global research landscape and, in terms of aggregate output, the United States has been the leading nation both for the discovery of new knowledge and for the training of future researchers. While a cure for diseases was seen as the ultimate goal of such research, the proximate goal was to secure a greater understanding of normal health and mechanisms of disease. Addressing this proximate goal typically drove discovery, with rewards coming from publications of one's research and for some biomedical scientists, global recognition through awards such as the Nobel Prizes or Lasker Awards. In such cases, the most successful investigators were recruited to prestigious academic centers that offered improved space and staff resources as well as higher financial compensation (e.g., higher salaries, advanced facilities). Importantly, through all these years, the NIH Bethesda Campus has offered an environment where researchers could pursue their lines of inquiry through use of animal models and working at the bedsides of patients typically cared for as inpatients at the NIH Clinical Center, located on the Bethesda Campus.

Overall, in this highly competitive global environment, the NIH Bethesda Campus faces much greater challenges than it once did in order to provide support facilities for emerging clinical medical problems and associated fundamental hypotheses regarding disease mechanisms. For example, many observers consider the overreaching paradigm for research to be much broader. Today, the overreaching paradigm for research is broader. The model has now evolved to one that is "biopsychosociotechnical," rather than simply "biomedical," recognizing that positive impacts from research on human health proceed from understanding and successfully impacting upon all relevant biological, psychological, sociological, and technological[1] dimensions relating to the condition. Far less frequently today is research able to deliver a singular preventive intervention or "cure" like that offered by the polio vaccine or thyroid hormone, although it still happens—as, for example, the development of Gleevec, for treatment of chronic myeloid leukemia, a condition once regarded as uniformly fatal. Major discoveries do continue, such as in the case of key molecules like nitric oxide or techniques such as CRISPR[2] gene editing. Based on the successes of past breakthroughs, public and elected officials increasingly seek not simply a better understanding of underlying disease mechanisms or a new drug or treatment that palliates or slows the progression of a dreaded health conditions, but instead seek "magic bullets" that cure or totally prevent such conditions. In addition to seeking cures, gaining "intellectual property" and spawning commercial success increasingly drives discovery, creating ethical dilemmas and sometimes catalyzing inappropriate behavior.

Research data that used to reside simply in paper records and then in the closely held databases of individual investigators are today increasingly shared on networks in the cloud. This is an era of bioinformatics, translational bioinformatics, clinical informatics, and population health informatics. The focus has grown from high-performance computing to cloud computing with growing national and global data networks such as those maintained by the National Library of Medicine, also located on the Bethesda Campus and comprising one of the 27 institutes and centers. Access to scientific literature has changed from the Index Medicus to PubMed and related sources of accessing the current state of knowledge. The drive continues toward an open science environment with greatly enhanced transparency and collaboration.

This latter trend is part of the move away from distinctive discipline-specific research. Researchers are required increasingly to broaden their competencies across traditional knowledge domains and co-locate in "scientific neighborhoods" of wet and dry labs for more efficient analysis and testing of current hypotheses. These inter- and intradisciplinary teams can take on bigger and broader topics. Additionally, there is now

---

[1] Sociotechnical systems are environments where humans work and interact with technology (Carayon, 2006; Pasmore, 1988). Complex adaptive systems are sociotechnical systems with key characteristics, which carry implications for designing work systems and processes. Plsek and Greenhalgh (2001) define complex adaptive systems as "a collection of individual agents with freedom to act in ways that are not totally predictable, and whose actions are interconnected so that one agent's actions change the context for other agents."

[2] Short for clustered regularly interspaced short palindromic repeats.

increased competition for talent, as the number and diversity of opportunities for young research talent has grown. Today, research organizations compete globally for young scientific talent who previously would have sought out NIH and were more eager to stay "in track" for years prior to advancing in stature. As the newer technologies mature, young researchers are increasingly seeking out and moving to other new and expanded research settings and teams.

Today, the "ordered chaos" of research enterprises—often like their clinical academic centers—function as complex adaptive systems in which core labs and computing clusters exist alongside each other and progress occurs through small gains in changing sets of high-priority questions. Incremental successes are often quickly worked into the fabric of the organization that allow new functionalities. Further, clinical research increasingly has moved from being almost entirely a hospital-based activity to one that often focuses on ambulatory patients. This has also occurred at the NIH Bethesda Campus's Clinical Center, which addresses unique and rare diseases that are not studied elsewhere. Overall, in this highly competitive global environment, the Bethesda Campus faces much greater challenges than it once did.

THE RESEARCH-BUILT ENVIRONMENT AND KEY EMERGENT TRENDS

The high costs of maintaining infrastructure that is not being actively utilized coupled with the desire to enhance greater productivity and more optimal working conditions had led to biomedical research facilities that are supported by architectural and engineering solutions offering flexibility and adaptability. These facilities must be designed to have flexible space, shared space, and multiple, diverse, and often social spaces used by teams of differing sizes and composition. In such spaces, teams share ideas, collaborate, and have efficient access to computer networks, databases, and communication systems that may span the globe. And while some research is still "slow going," the pace of discovery has materially accelerated overall.

Recent studies have identified the role of capital assets—equipment, built space, and supporting infrastructure—and their critical role in supporting and enhancing the research enterprise. Public and private organizations are increasingly considering a more complex mix for managing new capital assets for research facilities. Among the considerations are strategies that minimize "stranded space capital assets" and stretch the useful life of new facilities to sustain research discoveries with those features that improve retention and recruitment of scientists.

Perhaps the most widely acknowledged key trend impacting research infrastructure is the increased prominence of "big data," which simply means collecting massive amounts of raw data, storing it, and then analyzing it and disseminating the findings of the analyses, with the priority often being given to finding or creating actionable data.[3] Research enterprises must confront the issue of how much computing resources should they build and maintain on location versus relying on cloud computing capabilities. The considerations involve workforce, space, and perhaps most importantly, capacity to keep up with rapid innovations in information and communications technology including cybersecurity. Options allow one to leverage research performed across multiple geographically dispersed locations and can enhance collaboration between teams and disciplines. From a capital asset management perspective, this underscores the criticality of communications networks to ensure timely and protected transfer of this vast quantity of data, and the dependence of these communications networks on secure and reliable power sources.

A related trend is the development of "Lab on a Chip" (NASEM, 2018a, Chapter 1) modeling to complement and, in some cases, supplement in vivo research models (Gensleron, 2015). As computer-based modeling advances, laboratory facilities may be able to reduce space and resources dedicated to laboratory animal facilities and related capital assets. The reduction in living specimen facilities can significantly reduce mechanical and electrical loads and densities throughout laboratory facilities.

---

[3] D. Watch, 2016, "Trends in Lab Design," Whole Building Design Guide, National Institute of Building Sciences, updated August 29, https://www.wbdg.org/resources/trends-lab-design.

A third trend is the radical shifts in medical research equipment, including the introduction of robot-assisted surgical equipment and large-scale sample processing equipment (Fedler, 2014). This equipment is often larger than previous equipment, requiring increases in floor-to-floor heights and load-bearing structural capacities, as well as increasing densities and loads on mechanical and communications services throughout the laboratory facility.

As the nature and pace of biomedical research shifts and accelerates, public and private institutions are facing growing needs for rapidly adaptable research facilities. For some research organizations, changes in the performance of research require renovation of 25 percent or more of laboratory space each year.[4] The practical implications for potential capital project investments include reassessing structural, mechanical, and electrical system configuration to enable efficient and effective renovations—those specific investments that will reduce laboratory and clinical downtime and quickly facilitate changing research methodologies; fulfill equipment and related infrastructure needs; and create inspired places that will enhance the intensive work environments for scientific and clinical staff and clinical patients and visitors. The concept of "social buildings" that through architecture and flexible design facilitate intentional interactions and sharing of resources should be incorporated into the evaluation and capital planning process.[5]

Successful recruitment, retention, and scientific productivity of an institution's human resources can rely upon the nature of the collaboration possibilities, including direct opportunities for team-based research.[6] Research facilities will need to be designed and managed to emphasize easy and effective cross-team collaboration through a variety of working and meeting spaces that are designed to enhance staff interaction and productivity and clinical patient health and recovery improvements.

One additional trend suggests increased research collaboration among public and private organizations, often facilitated by science conducted with shared facilities that include high-cost and specialized equipment and shared clinical capital assets (ACRP, 2018). (See the discussion in Chapter 3, in the section "Selected Extramural and Intramural Research Program Collaborations.") Since the complexity and risks associated with more rapid research advancements combined with clinical trials are increasing, co-location of activities can significantly improve research and trial outcomes. While some research organizations create special areas or campuses for these interaction teams, others complement current facilities with available visitor spaces. The impacts to the research-built environment can include modifying access security and protocols, reconfiguring workspaces to accommodate visiting teams, and, as noted, earlier, creating adaptable spaces that can be reconfigured efficiently as needed. The multi-institute facilities at NIH are discussed in Chapter 3.

SUMMARY

The nature of and environment in which biomedical research is conducted has materially changed in recent decades and promises to change even more in the years ahead. These changes have implications that may affect the character of the research-built environment and operations of the NIH Bethesda Campus. This is also true for all scholarly (e.g., training) programs attached to the clinical research components.

---

[4] D. Watch and D. Tolat, 2017, "Research Laboratory," Whole Building Design Guide, National Institute of Building Sciences, updated May 16, https://www.wbdg.org/building-types/research-facilities/research-laboratory.

[5] D. Watch, 2016, "Trends in Lab Design," Whole Building Design Guide, National Institute of Building Sciences, updated August 29, https://www.wbdg.org/resources/trends-lab-design.

[6] Ibid.

3

NIH Bethesda Campus: Facilities and Activities

OVERVIEW OF MISSION (INTRAMURAL, EXTRAMURAL)

Among its tasks, the committee has been asked to identify potential factors and approaches that the National Institutes of Health (NIH) should consider in developing a comprehensive capital strategy for its main campus portfolio of facilities to span from 5 to 20 years into the future. To respond to this task, it is important to review in some detail the history and culture of NIH and of the Bethesda Campus in particular. The administrative heart of the entire NIH is located there, as well as the largest dedicated research hospital in the world, in addition to acres of research space and research support services.

Mission of NIH

The 27 institutes and centers (ICs) that comprise NIH have diverse missions and areas of focus. The NIH leadership expresses the collective goal of these organizations in broad terms as follows:[1]

- To foster fundamental creative discoveries, innovative research strategies, and their applications as a basis for ultimately protecting and improving health;
- To develop, maintain, and renew scientific human and physical resources that will ensure the nation's capability to prevent disease;
- To expand the knowledge base in medical and associated sciences in order to enhance the nation's economic well-being and ensure a continued high return on the public investment in research; and
- To exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science.

[1] P.A. Sieving, National Eye Institute, and D. Wheeland, NIH Office of Research Facilities, 2018, "Orientation to the NIH," presentation to the committee on March 20.

History and Description of the NIH Bethesda Campus

The NIH Bethesda Campus (NIH-BC) includes a large intramural research program nested within an administrative structure that offers central oversight over all NIH activities, including intramural and extramural programs. The intramural programs are located on the campus and sites nearby (with a few exceptions), whereas the extramural programs, which constitute most of NIH's research expenditures, are not performed by NIH and are located nationwide.

In fiscal year (FY) 2018, NIH had total budget authority of $37.3 billion, about one-tenth of which supports its own intramural research laboratories, most of which are in Bethesda.[2] Of the nearly 6,000 scientists who work at NIH, some 1,117 are principal investigators (PIs; FY 2018) and over 4,000 are postdoctoral fellows who are both conducting research and honing their research skills. The role of NIH over the years in the creation of well-trained bench and clinical scientists has been profound. When one studies the background sketches of members in the National Academies of Science, Engineering, and Medicine, early experiences at NIH and its Clinical Center are frequently noted.

In colloquial language, most of the ICs relate to the study of body parts or conditions such as cancer, eye and heart disease, aging, allergies and infectious diseases, and neurological disorders. Other ICs such as the National Institute of Nursing Research, National Institute of Biomedical Imaging and Bioengineering, Institute of General Medical Sciences, National Library of Medicine, and Fogarty International Center have a broader focus. Eleven percent of the budget supports the intramural programs that are located largely on the Bethesda Campus; the remaining 89 percent supports the extramural research activities conducted at diverse locations across the nation and world.

The Bethesda Campus consists of 310 acres of land in Montgomery County, Maryland, just north of the downtown area of the unincorporated city of Bethesda. The Walter Reed National Medical Military Center is located immediately across Wisconsin Avenue at the eastern boundary of the campus. Animal facilities are located on campus, as well as at Poolesville, Maryland. Some campus facilities house administrative activities that support the research programs; other administrative activities are housed in leased space in the Washington, D.C., metropolitan area but are considered part of the NIH Bethesda Campus. While the bulk of the intramural investigators and postdoctoral fellows are located on the Bethesda Campus, the Intramural Research Program (IRP) also has facilities at the Research Triangle Park in North Carolina; the Bayview Campus in Baltimore, Maryland; the Frederick National Laboratory for Cancer Research in Frederick, Maryland; Rocky Mountain Laboratories in Hamilton, Montana; and the Phoenix Environmental and Clinical Research Branch in Phoenix, Arizona (Figure 3.1).[3]

Starting with the Ransdell Act in 1930,[4] which changed the name of the Hygienic Laboratory to the National Institutes of Health, research fellowships have been supported. The NCI was designated as a component of NIH in 1944, and between 1947 and 1966, its budget grew from $8 million to over $1 billion. The NIH Clinical Center opened in 1953 with 540 beds (now 200 beds) and is the largest hospital in the world dedicated solely to biomedical and health research. Today, the Clinical Center includes an 870,000 square foot (SF) newer facility with 200 inpatient beds and 93 day-hospital stations, with some departments and ambulatory care in parts of the original 14-story Warren G. Magnuson Clinical Center. About 1,600 clinical research studies are in progress today at the Clinical Center, of which about half are devoted to rare human conditions that are often not studied anywhere else. Conducting clinical trials is a major part of the Clinical Center's work, focusing predominately on first-in-human studies that test the safety and efficacy of potential new treatments. See Appendix D for additional statistics relating to inpatient clinical volumes and outpatient activities.

---

[2] Overall, NIH is comprised of 27 ICs whose annual budgets range from the National Cancer Institute (NCI) with nearly $6 billion in FY 2018 down to a couple who each receive less than $100 million.

[3] NIH Intramural Research Program, "Research Campus Locations," https://irp.nih.gov/about-us/research-campus-locations, accessed March 20, 2018.

[4] Public Law 71-251; codified as 42 U.S.C. § 21 et seq.

FIGURE 3.1 NIH properties that form part of the Intramural Research Program. SOURCE: NIH Office of Research Facilities, Bethesda, Md.

How the Organization Addresses the Needs of the Facilities

Organizational Structure

The structure and organization of NIH, in comparison to most biomedical research organizations, is driven by some of its peculiar features (e.g., being entirely government funded, its political as well as policy support particularly within the legislative branch) and strong external public advocacy groups. While there is an NIH Director who is presidentially appointed and Senate confirmed, he or she oversees a confederation of variably independently operated ICs rather than exercises central control. Perhaps, the most compelling example is the NCI, whose Director is a presidential appointee. This stature gives the NCI virtually total control over its operations and planning. While the institute directors have a weekly hour-and-a-half meeting with the Director, most planning and facilities issues reside within each IC. To some extent, an NIH resource committee and an institute directors' "executive committee" also consider physical resources. All of this results in a very complicated structure for planning and managing facilities.

Most ICs at NIH relate to organs or body systems and specific diseases, while others relate to disciplines or areas of interest. For example, with the exception of research in the Clinical Center, the NCI does its research in facilities located at the Frederick National Laboratory located 50 miles northwest of Washington, D.C., and the Shady Grove Campus (see Figure 3.1); NCI made that decision more or less independently. The activities of the National Institute of Allergy and Infectious Diseases (NAIAD) are of similar scope and scale and, recently, the Institute on Aging has begun assuming this status.

Expansions to the research mission of NIH or for new facilities on the NIH campus have resulted at times from effective advocacy from external persons or organizations working in concert with NIH units to influence prominent members of the Congress to support NIH. Once it becomes apparent that Congress does want to move an area of investigation forward or add a facility on the NIH Bethesda Campus, the Director then becomes supportive and plans move forward (Smith, 2008).

Funding for Buildings and Facilities

As will be discussed further in Chapter 4, money spent on facilities addresses construction, repairs and improvements, and maintenance. Funds come from a number of sources including the Buildings and Facilities line item in the congressional appropriation, a nonrecurring expense fund (from the Department of Health and Human Services [HHS]), and one-time appropriations. A small allocation can come from individual institute operating funds (known as special authority, a reference to its origin in the appropriations bills) or from centrally administered funds such as the Capital Improvement Fund using deposits from the IC's appropriated funds.

Maintaining the condition of facilities is a complex enterprise. An impression exists within a number of NIH ICs that in-house maintenance cannot be depended upon to fix problems within buildings, so the ICs hire special contractors to do some needed work. The waitlist for alterations or repairs is frequently a year or two even for small changes such as redesigning or building small offices. The basement in the Lister Hill Center, part of the National Library of Medicine, has sustained water leaks on at least four separate occasions over the years. The committee witnessed similar leaks in laboratories in the new Porter Neuroscience Research Center.

Perhaps a larger problem is the scale and management of leased buildings across Montgomery County in particular. Approximately thirty buildings are rented, and a number are either miles from the Metro, the Washington-area subway system, or have limited parking and transportations. A few are in transportation oases. One at 6100 Executive Boulevard suffered a recent major structural issue. A supporting column suffered a rust collapse of approximately an inch (NIH, 2014a). The building was evacuated, and the county essentially determined it uninhabitable for some weeks while remediation was done. At present, the building is in foreclosure, with only three of eight floors occupied. Apparently, the current plan is to move the remaining NIH staff to the Rockledge area of leased space in Rockville in 2020.

Additionally, the Bethesda Campus is challenged by the dearth of all-weather connectors among the buildings at NIH above ground and connectors for people to walk below grade. Such connectors are common in other biomedical research complexes and are a cost-effective way to promote collaboration.

Where growth has exceeded available land, new large parcels of land have been obtained. Excellent transportation mechanisms have been established to minimize the disconnections. At NIH, the various individual ICs have leased property throughout Montgomery County with radically varying transportation options among them. The committee was unable to determine the rationale behind this artificial separation of the various NIH units on the Bethesda Campus and believes it warrants reconsideration to achieve greater productivity.

Funding and Personnel

In assessing current and future space requirements in size and nature, it is of course relevant to consider the resources available for salaries and the size and distribution of personnel on the NIH campus needed to meet its mission. What follows here is a description of this matter, including how the current configuration of space and also access to facilities on the campus influence meeting the mission of NIH as a premier research campus.

Funding

The budget authority (appropriated funds) for NIH in FY 2018 totaled $37.3 billion (see Figure 3.2), with close to 90 percent for extramural programs. Not every one of the 27 ICs receives a line-item appropriation; in fact, three of the centers are funded by the NIH Management Fund, which receives

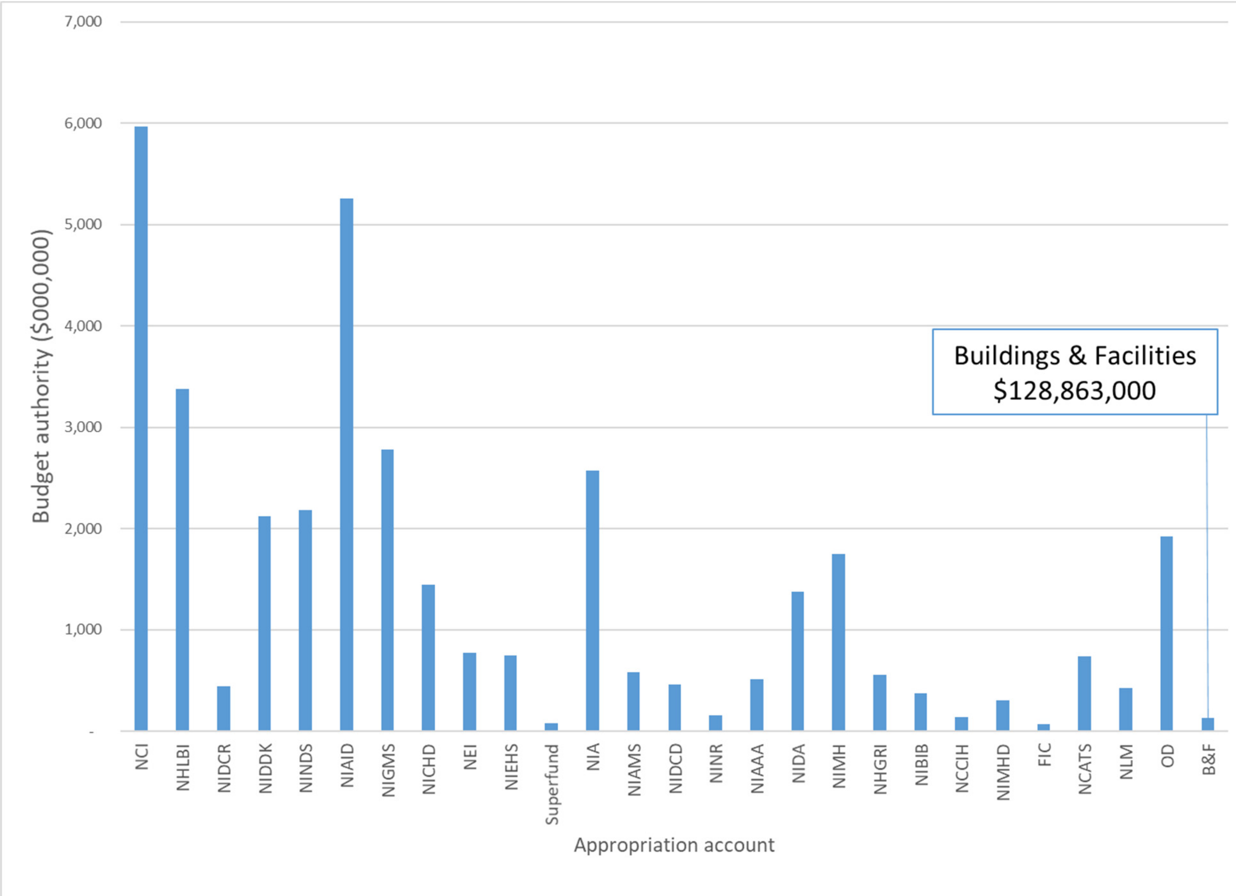


FIGURE 3.2 National Institutes of Health (NIH) Budget Authority by Appropriation Account FY 2018. NOTE: Acronyms listed in Appendix K. SOURCE: Neil K. Shapiro, NIH, "The NIH Budget," presentation to the committee on May 16, 2018.

deposits from the various institutes from their appropriation accounts.[5] The Clinical Center was thus funded in FY 2018 at $495 million and the Center for Scientific Review at $140 million (HHS, 2019).

Over the decades, the NIH campus has been a leader in developing the nation's biomedical research workforce. During the 1960s, 1970s, and 1980s, clinical associates trained at NIH went into academic medical careers across the nation. Some stayed at NIH for their entire career or were recruited back to NIH to be investigators. Today, while there are still large numbers of personnel of differing categories, the challenge of attracting and keeping top-flight talent is much more difficult owing to, among other things, less than competitive salaries, deteriorating facilities, greater philanthropic support at private centers, and the rise of competitive international research centers.

[5] For example, the National Cancer Institute provided $137.4 million in FY 2018 for the Management Fund (NIH NCI, 2018b).

TABLE 3.1 NIH Full-Time Equivalent Employees by Institute or Center for Fiscal Year (FY) 2017

Institute/Center	FY 2017	FY 2017 Total (%)
NCI	3,029	17
NIAID	1,959	11
NHLBI	955	5
NIEHS	658	4
OD	785	4
NLM	733	4
Central Services	4,596	26
Other ICs	5,303	29
Total NIH FTE	18,018	100

NOTE: IC, institute or center; NCI, National Cancer Institute; NHLBI, National Heart, Lung, and Blood Institute; NIAID, National Institute of Allergy and Infectious Diseases; NIEHS, National Institute of Environmental Health Sciences; NLM, National Library of Medicine; OD, Office of the Director.
SOURCE: NIH, "Full-Time Equivalents by Institute and Center (IC): FY 2000 to FY 2017," https://officeofbudget.od.nih.gov/pdfs/FY19/FTEs by IC FY 2000 – FY 2017 (V).pdf, accessed January 30, 2019.

Workforce

In FY 2017, NIH had over 18,000 full-time equivalent (FTE) employees, with 26 percent assigned to NIH General Services (such as the Office of Research Facilities and Office of Research Services [ORS]), 17 percent assigned to NCI, and 11 percent to NIAID (see Table 3.1).

Approximately 21,000 staff, counting those who are not federal full-time equivalent employees, work on the NIH Bethesda Campus (Neibauer, 2015; NIH, 2015a); this is expected to increase to 23,000 according to the document *2013 Comprehensive Master Plan—Bethesda Campus* (NIH ORF, 2013). Some of these additional personnel will be existing staff who currently work in off-campus leased space.

The IRP in FY 2018 employed 3,454 full-time equivalent research professionals and hosted over 5,500 non-FTE trainees. Of the full-time research professionals, 1,117 are principal investigators (32 percent of total Intramural Professional Designation), of which 28 percent are women (see Table 3.2). Of the 2,487 research personnel that are not designated as principal investigators, 42 percent are women. In FY 2017, 1 percent of the principal investigators were foreign nationals, with 9 percent of foreign nationals as research personnel not designated PIs, and 28 percent of the non-FTE trainees.

Today, the mix of personnel engaged in the IRP is changing in a way that deserves attention. All categories of staff have been on a slow downward trend over the past 8 years except for staff scientists, who have been sharply increasing, essentially doubling during this period (see Figure 3.3). Complete data are not available.

According to the NIH description of staff scientists, they are doctoral-level scientists selected to support the long-term research of a PI or as a member or head of a core facility. As such, "staff scientists do not receive independent research resources, although they often work independently and have sophisticated skills and knowledge essential to the work of the laboratory. Staff Scientists are capable of independently designing experiments, but do not have responsibilities for initiating new research programs."[6] It would be helpful to know if such a dramatic shift has been seen at other biomedical research institutions or if the IRP experience is an outlier.

[6] NIH Office of Intramural Research, "IPDs and Appointment Mechanisms," https://oir.nih.gov/sourcebook/personnel/ipds-appointment-mechanisms, accessed October 18, 2018.

TABLE 3.2 Intramural Research Personnel Demographics, Fiscal Year 2018

Classification	Total	Proportion Female by IPD (%)	Proportion Male by IPD (%)	Proportion Foreign Nationals by IPD (%)
Principal investigator (IPD)	1,117	28	72	1
Non-principal investigator (IPD)	2,337	42	58	9
Non-FTE trainees	5,590	NA	NA	28
Total	9,087			

NOTE: FTE, full-time equivalent; IPD, Intramural Professional Designation; NA, not applicable; PI, principal investigator.
SOURCE: National Institutes of Health, Office of Intramural Research, "IRP Demographics," https://oir.nih.gov/sourcebook/personnel/irp-demographics, accessed January 30, 2019.

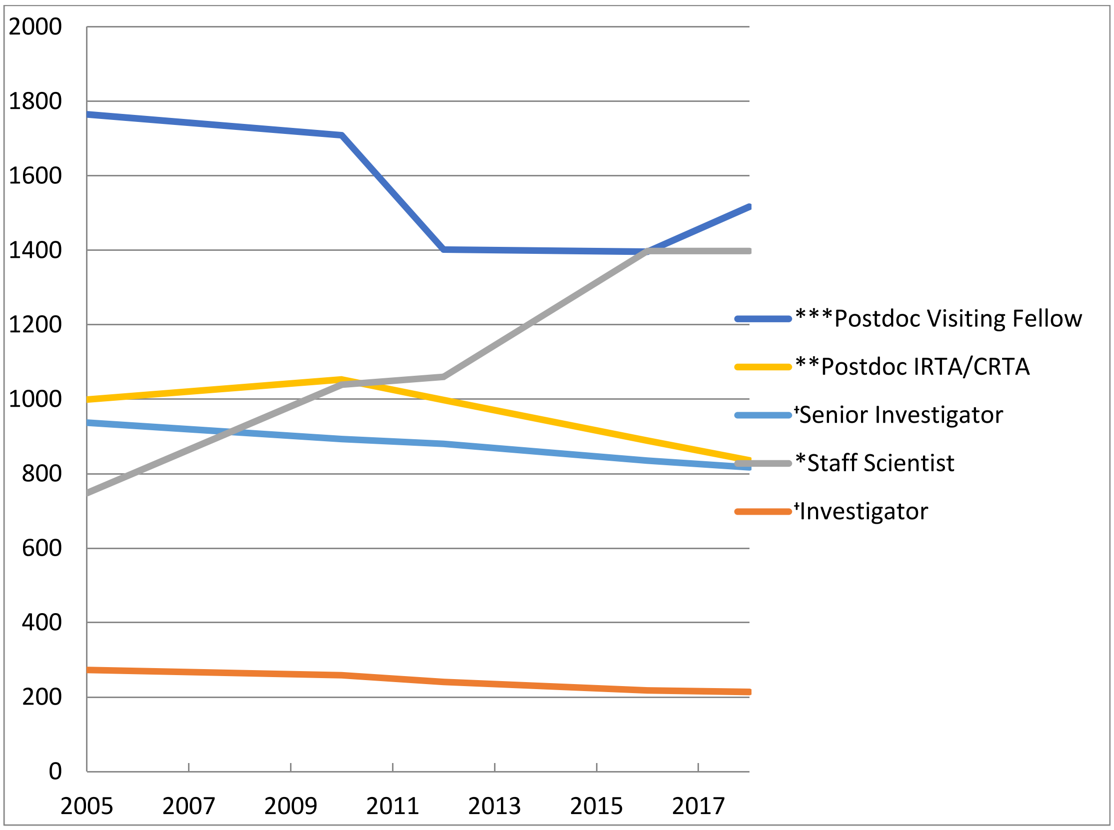


FIGURE 3.3 Trends in selected categories of National Institutes of Health (NIH) staff over the past 8 years. NOTE: CRTA, Cancer Research Training Award; IRTA, Intramural Research Training Award. SOURCE: NIH, Intramural Research Program, "IRP Personnel Trends 2005-2018," via e-mail, October 18, 2018.

From 2005 to 2018, the number of senior investigators has decreased from 937 to 817, a drop of 15 percent. An even larger decrease in investigators has occurred—from 273 to 214, a 27 percent drop. Clinical fellows are doctoral-level health professionals with an interest in biomedical research relevant to NIH program needs who are employed on a time-limited appointment. Clinical fellows participate in protocol-based clinical research, as well as laboratory research. Scientists with considerable experience beyond postdoctoral training (PGY-9 equivalent or beyond) may be designated senior clinical fellow,[7] if they fulfill

[7] See http://sourcebook.od.nih.gov/prof-desig/DDM%20memo%20re%20NIH%20T42%20Pay%20Model%20Modification.pdf.

the competitive selection requirements. Clinical and senior clinical fellows have dropped from 342 to 279, a decrease of over 20 percent. Postdoctoral fellows have gone from 1,765 to 1,517, a decrease of 15 percent. Staff clinicians have increased somewhat, while the numbers of predoctoral IRTA/CRTAs (Intramural Research Training Award, denominated CRTA at NCI) is stable and postdoctoral IRTA/CRTAs have gone down nearly 20 percent. Post-baccalaureate IRTA/CRTAs have increased by nearly 50 percent. Clearly, there are reasons underlying these workforce trends, but determining such reasons was beyond the committee's charge.

NIH, NATIONAL SECURITY, AND THE BETHESDA CAMPUS

NIH Contributions to the Nation's Health Security

The NIH is a vital element in the nation's health security.[8] The Public Health Emergency Medical Countermeasures Enterprise (PHEMCE) is led by the HHS Office of the Assistant Secretary for Preparedness and Response and coordinates federal efforts to enhance preparedness and response from a medical countermeasure prospective to chemical, biological, radiological, and nuclear threats and emerging infectious diseases. The Centers for Disease Control and Prevention, the Food and Drug Administration, and NIH are the primary internal HHS partners working in close collaboration with numerous interagency partners including the Departments of Defense, Veterans Affairs, and Homeland Security, and the U.S. Department of Agriculture to support the PHEMCE mission (Figure 3.4).[9]

In this national security effort, NIH is focused on early-stage research to better understand the threats to civilian public health and to identify strategies to develop new treatments, medical products, and ways to diagnose, treat, and hopefully prevent health threats.[10] In FY 2017, the largest proportion of multiple-hazard and preparedness funding in HHS was provided to Biodefense and Emerging Infectious Disease Research ($1.74 billion of combined intramural and extramural funding) at NIH (Boddie et al., 2016). As demonstrated during the 2014 Ebola outbreak, NIH is uniquely positioned to partner with industry and other stakeholders during times of national emergencies and to conduct essential clinical trials needed to accelerate the development of new treatments to fight epidemics and new infectious diseases. The NIH Mark O. Hatfield Clinical Research Center on the Bethesda Campus remains one of a few global research facilities with the ready capacity to isolate patients to control the further spread of a disease, prepare novel therapies, and conduct clinical trials in a controlled and safe environment (NASEM, 2016).

NIH Contributions to the Nation's Economic Security

In addition to reducing the economic and social burdens of illness and disability, NIH research funding continues to sustain significant contributions to direct research and related job creation, as well as economic impacts delivered through the commericialization of biomedical innovation and resulting products development and distribution, as follows:[11]

---

[8] National health security is defined as a state in which the country and its people prepare for, protect from, and become resilient to incidents that have the potential to cause extensive disruption and damage to the public health and to U.S. and global economies. See HHS (2014); HHS Public Health Emergency, "PHEMCE Mission Components," updated February 27, 2015, https://www.phe.gov/Preparedness/mcm/phemce/Pages/mission.aspx; Watson (2017); and Boddie et al. (2016).

[9] HHS Public Health Emergency, "PHEMCE Mission Components," updated February 27, 2015, https://www.phe.gov/Preparedness/mcm/phemce/Pages/mission.aspx.

[10] Ibid.

[11] See Ehrlich (2018) and NIH, "Our Society," reviewed May 1, 2018, https://www.nih.gov/about-nih/what-we-do/impact-nih-research/our-society.

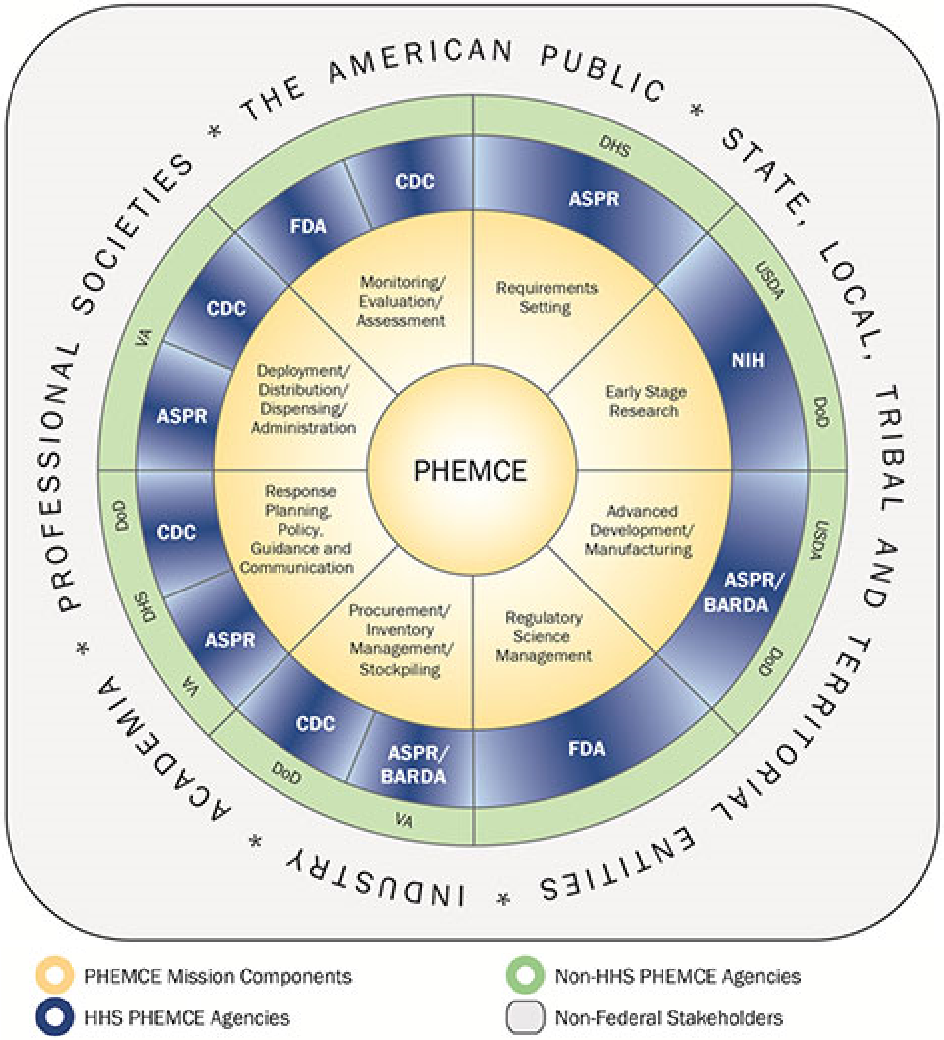


FIGURE 3.4 Schematic of coordination role of Public Health Emergency Medical Countermeasures Enterprise (PHEMCE). NOTE: Acronyms can be found in Appendix K. SOURCE: Department of Homeland Security.

- "NIH investments in research focused on a particular area stimulate increased private investment in the same area" (Azouly, 2015). "A $1.00 increase in public basic research stimulates an additional *$8.38 of industry R&D investment* after 8 years. A $1.00 increase in public clinical research stimulates an additional *$2.35 of industry R&D [research and development] investment* after 3 years" (Toole, 2007).
- "NIH-funded basic research fuels the *entry of new drugs into the market* and provides a *positive return to public investment* of 43%, by some estimates" (Toole, 2007, 2012).
- "Using the Regional Input-Output Modeling System (RIMS II) developed by the Department of Commerce, United for Medical Research calculated the impact of NIH research funding in 2017 on jobs and the economy . . . NIH research funding in 2017 directly and indirectly supported 402,816 jobs nationwide. Thirteen states have employment of 10,000 or more supported by NIH research funding and the median state has 4,014 jobs due to NIH activity. Additionally, the income generated by these jobs, as well as by the purchase of research

> related equipment, services and materials, when cycled through the economy, produced $68.795 billion in new economic activity in 2017" (United for Medical Research, 2018).

Security Considerations and Access to the NIH Bethesda Campus

Until 9/11, the NIH Bethesda Campus was open and freely accessible. Security was building- or use-specific with a focus primarily on the central vivarium, smaller vivaria embedded in institutes, and certain laboratory facilities with functions and missions that required secure environments. The campus enjoyed access by vehicles and pedestrians from all surrounding campus streets with no discrimination between visitors, researchers, staff, patients, and vendors. The most pressing vehicular issue was not security but was parking, and open parking for visitors and staff was even permitted underneath the Ambulatory Clinical Research Center.

Today, operational security measures in place at the NIH campus have been addressed holistically, at multiple scales and utilizing an all-hazards resilience planning and recovery approach. After 9/11, NIH completely transformed the campus from an open one to one today that has limited, controlled access and a sophisticated physical security perimeter. Individual facilities with limited access are part of a larger comprehensive system of security.

The *2013 Comprehensive Master Plan—NIH Bethesda Campus* (NIH ORF, 2013) refers to security consideration as follows:

> **Security Considerations**
>
> The Director, NIH has delegated authority for the protection of NIH facilities and grounds to the Associate Director for Research Services (ADRS) and the Associate Director, Security and Emergency Response, ORS. The Security and Emergency Response (SER) services support the NIH's biomedical research goal, by providing a safe work environment for the NIH employees, contractors, affiliates, visitors, research and facilities. All facility projects shall be coordinated with SER. The services within SER are:
>
> - Division of Police (DP),
> - Division of Emergency Preparedness and Coordination (DEPC),
> - Division of the Fire Marshal (DFM),
> - Division of Fire and Rescue Services (DFRS),
> - Division of Physical Security Management (DPSM),
> - Division of Personnel Security and Access Control (DPSAC).

The security management measures for the NIH-BC includes use of campus perimeter fencing that has incorporated surveillance systems of cameras and other sensors. Access control is limited to eight entry gates and access portals. The public, including all NIH staff and NIH visitors, must enter only at the Gateway Center (see Chapter 4, Figure 4.2) near the Metro Center portal on Wisconsin Avenue, where they are screened and issued temporary access. All service vehicles and trucks are inspected and screened for site access only at the gate on the northeast corner of the site. Employees are permitted access at six designated portals, where they are processed and screened utilizing individual ID passes. Patients access the campus at a dedicated portal off West Cedar Lane on the north perimeter, where the Clinical Research Center provides a listing of expected patient arrivals on a daily basis.

The Mark O. Hatfield Clinical Research Center is always open to the general public. Although the main lobby functions as a point of central control and inspection, there are numerous points of entry widely scattered in and around the center, all of which remain open 24 hours a day. Ongoing security considerations include assessment of the operational impacts of reducing the number of access portals to the center. In addition, over the years there has been discussion regarding potential enhanced security measures associated with maintaining or eliminating the vehicular parking located below the Ambulatory Clinical Research Facility portion of the Clinical Research Center. Vehicles are currently permitted access to this below-grade parking structure following extensive screening prior to entry. The clinical laboratory zone of the Clinical Research Center is open during the working day but is secured from 6 PM to 7 AM, with access limited to use of an access control system (currently keypad operated). Consistent with all clinical facilities, specific functional areas are secure at all times, including the mental health unit, medications and pharmacy, medical records, and mechanical and other building system support areas. Campus-wide, animal care facilities and a majority of NIH Bethesda Campus facilities utilize access control and allow access only if the individual holds NIH-approved identification.

VALUE AND ACCOMPLISHMENTS OF NIH INTRAMURAL PROGRAM

NIH IRP Level of Investment in an International Context

Scientific discoveries are costly, especially in today's technology-driven, rapidly changing, multidisciplinary global research environment. They require extensive training and a long-term commitment by scientists devoted to their fields, as well as a significant investment by the public, who ultimately benefit in improved health outcome, reduced illness and disability, and increased life expectancy. While the United States has been able to maintain its leadership in past times of funding uncertainties, the lack of significant increases in IRP funding has raised concerns among some observers that NIH, and the United States in general, may lose its global edge in such metrics as scientific research articles, patents, and technology workforce development (Moses et al., 2015).

This concern is supported by the increase in research infrastructure funding in Europe, in particular in the European Union (EU) as part of the EU 2020 effort, and a relative decline in public and private sector R&D expenditures in the United States (compound annual growth rate of 1.9 percent for 2007-2012, adjusted for inflation), as compared to an increase of 32.8 percent in China and 10-11 percent in South Korea and Singapore (Chakma et al., 2014; Moses et al., 2015). When compared to China, the U.S. readout of research output during 2000-2015 based on original articles from U.S.-based authors published in high-ranking clinical and basic science journals declined, whereas China-based investigators' output in mid- and high-ranking journals steadily increased over the same time period (Conte, 2017).

While the United States is reducing federal funding for R&D, the EU has made major investments under the EU 2020 strategy in building the European Research and Innovation Area to provide open access to scientific resources and services for all scientists across Europe (ESFRI, 2016; EMRC, 2011; Smith et al., 2011). The EU has over 500 research infrastructures (RIs), with over 300 RIs having strong international visibility that attracts world-class researchers. Supported by an investment of over 100 billion euros, the RIs are conceived, funded, and managed as open research institutes to attract scientists from around the world, and drive excellence in innovation to ensure that the EU economy remains competitive (ESFRI, 2016). Located across the EU, the RIs are seen as high-performance platforms for cooperation among universities, enterprises, and research institutions. While there is a wide gap between research productivity among EU countries, there is strong commitment to develop a diverse research workforce, engage the public, and build a shared research infrastructure across the member countries.[12] The new EU Coordinated Research Infrastructures Building Enduring Life-Science Services (CORBEL) consortium brings together 13 new state-of-the-art Biological and Medical Sciences RIs, including biological data, physical biobank samples, imaging facilities, and molecular screening centers to boost the efficiency, productivity and impact of European biomedical research. Both China and Europe have placed a great emphasis on international collaborations. While in the past the evaluations of collaborations based on existing literature have primarily focused on China and U.S. collaboration, more recently China and EU collaborations have increased owing to the EU's integration strategy, which has a special emphasis on the strategic linkage of EU member states with middle or low scientific capacity and China (Wang et al., 2017). The number of papers co-authored

---

[12] See the CORBEL Shared Services for Life-Science website at http://www.corbel-project.eu/about-corbel/corbel-partner.html.

by Chinese and European authors increased from 2,500 in the year 2000 to more than 19,000 in 2014. This makes China the second most prolific external EU partner after the United States (Wang et al., 2017). In addition to focusing on international collaboration, China is making significant investments in research infrastructure with a focus on translational research. The National Centre for Translational Medicine in Shanghai is the first of five translational research centers under development (Williams, 2016).

Given China's investment in biomedical infrastructure and international collaboration, Senator Bill Nelson of Florida warned at a January 2018 congressional hearing on the state of American science: "At this rate, China may soon eclipse the U.S. and we will lose the competitive advantage that has made us the most powerful economy in the world" (Guarino, 2018).

Intramural Assets

Cores

Scientific Core Facilities

In response to the Advisory Committee to the Director's (ACD's) report, *Long-Term Intramural Research Program (LT-IRP) Planning Working Group Report* (NIH ACD, 2014), the 2015 NIH Response and Implementation Plan (NIH ACD, 2015) outlined that the use of the IRP's research infrastructure was historically not strategically integrated or optimized to build efficiencies, ensure awareness, or expand access to investigators across the ICs of the IRP. Funding, administration, and access to instrumentation and core facilities[13] varied widely across the IRP—ranging from those shared by multiple ICs to those funded by individual ICs or lab-/branch-specific funding. Until recently, no central catalogue was available that listed the complete inventory of the IRP core facilities.

In 2017, the NIH IRP adopted the NCI's system as the NIH-wide Collaborative Research Exchange (CREx)—a marketplace connecting IRP investigators with 110+ IRP cores, including many trans-NIH cores and 10,000+ external vendors.[14] The majority of the 110 core facilities are sponsored by NCI and 10 ICs, with most of the trans-NIH-wide operated facilities being supported by either the Clinical Center (CC) or ORS (Gottesman and Baxevanix, 2017).

The services provided by the cores are wide ranging, from the NCI's nanotechnology core; the National Institute of Diabetes and Digestive and Kidney Diseases mouse knockout core tasked with producing transgenic mice; the National Heart, Lung, and Blood Institute biochemistry facility; as well as an extensive list of multiple imaging, microscopy, genomics, and proteomics cores across the ICs.[15] In 2017, the Office of Intramural Research (OIR) Director's Challenge Fund provided the initial funding to implement CREx, with commitments by the ICs and OIR to support this effort in the long term. The Shared Resources Subcommittee of the Board of Scientific Directors oversees multiple trans-NIH initiatives and facilities supported by voluntary contributions from the IC IRPs. Contributions are based partially on the size of the IC IRP's budget and on the IC's use of the facility.

CREx access is limited to NIH investigators, who have the ability to compare cost and services of NIH-based and outside-based vendors, in addition to giving feedback on service quality. The system's reporting tools can guide decision making in regard to prioritization of which internal cores to support and when to redirect resources to fund emerging technologies (Gottesman and Baxevanix, 2017). The recent implementation of CREx is a significant step toward providing access to core services across the IRP.

[13] Core facilities are centralized shared research resources that provide access to instruments, technologies, and services, as well as expert consultation and other services to scientific and clinical investigators. See NIH, "Frequently Asked Questions," revised April 18, 2018, https://grants.nih.gov/grants/policy/core_facilities_faqs.htm.

[14] The site can be accessed by those with log-in credentials at https://nih.scientist.com/users/sign_in.

[15] See NIH Intramural Research Program, "Research Resources," https://irp.nih.gov/our-research/research-resources, accessed April 1, 2019. Cores also include such capabilities as single-cell genomics, cryo-electron microscopy, RNA interference, PET and MR imaging, drug candidate screening, natural products, mass spectrometry, transgenic facilities, combinatorial chemistry, bioinformatics and computational biology.

However, it is likely that redundant core resources were developed by ICs, given the lack of a comprehensive central system to track the core facilities, available utilization, and incentives to integrate core resources.

In responses to the Advisory Committee Report, critical new technology needs were identified. Requests include technology incubators, optical microscopy, instrument development, clinical imaging, and enhanced computational resources to support big data analysis.

To support the strategic core integration plan, new payment models are being implemented for easy transfer of funds from one IC to another to cover service costs. In addition, the SRC model for more expensive shared cores will be extended to include shared large capital equipment purchases of emerging novel technologies (NIH ACD, 2015).

Compared to the IRP, NIH has long invested in the integration of NIH-supported core facilities and services in the extramural program. Given the NIH investment in extramural research infrastructure, totaling approximately $900 million in 2015, the consolidation of core facilities has been a strategic priority. For large grant programs such as the NCI Cancer Centers and Clinical and Translational Science Awards program supported by National Center for Advancing Translational Sciences, NIH has emphasized that research organizations receiving support must implement programs to enhance core resource efficiencies (Chang and Grieder, 2016; Farber and Weiss, 2011; Reeves et al., 2013). Recently published results of an NIH pilot program, conducted under the American Recovery and Reinvestment Act, indicated that financial incentives that support centralization of core services can successfully optimize core administration, increase efficiencies, and eliminate redundancy (Chang et al., 2015; NIH ACD, 2015). This justifies the large investment in the advanced, high-throughput instrumentation and expertise. A similar approach should be considered to bring efficiencies to the IRP research cores.

Animal Facilities

The NIH provides an extensive animal research infrastructure at the Bethesda Campus as well as at the NIH animal center in Poolesville, Maryland, for IRP investigators.

The role of the Division of Veterinary Resources (DVR) of the IRP may be described as follows:[16]

> DVR supports the NIH Community by providing facility management services, housing and husbandry, veterinary and critical care, quarantine, enrichment, and nutrition. DVR manages 11 buildings encompassing 300,000 gross square feet of animal housing and laboratory space at the NIH Bethesda campus, and 7 buildings encompassing 150,000 gross square feet of animal housing space at the 513 acre NIH animal center in Poolesville, Maryland. DVR provides housing for approximately 100,000 animals, primarily rodents, but for rabbits, primates, carnivores, and ungulates as well. DVR has the capability of housing animals in conventional, SPF, or hazard containment environments.[17]
>
> As the central NIH laboratory animal support program, DVR serves NIH intramural investigators by providing a full range of essential and specialized veterinary services. In addition, DVR professional staff is available for consultation on all aspects of laboratory animal medicine and to participate in collaborative research. [Services include] clinical care, diagnostics, environmental enrichment, facility management, genetic monitoring, health surveillance, husbandry, intensive care, nutrition, pharmacy, phenotyping mouse models, procurement, quarantine/conditioning, radiology, surgery, and transportation.[18]

---

[16] NIH Office of Management, Division of Veterinary Resources, https://www.ors.od.nih.gov/sr/dvr/Pages/default.aspx, accessed March 8, 2019.

[17] NIH Office of Management, "Animal Facility Management," https://www.ors.od.nih.gov/sr/dvr/facility/Pages/AnimalFacilityManagement.aspx, accessed March 8, 2019.

[18] NIH Office of Management, "DVR," https://www.ors.od.nih.gov/sr/dvr/Pages/default.aspx?, accessed March 8, 2019.

The DVR program is AAALAC[19] accredited. In addition, several of the ICs run smaller vivarium facilities, as well as specialized animal resource cores. Of the 23 buildings housing vivarium functions, greater than 50 percent are more than 45 years old. The Building 14/28 complex is the largest holding facility on the Bethesda Campus and the only one not connected to a laboratory building. The complex is lacking essential mechanical infrastructure upgrades to reliably maintain the facility. The long-term plans (NIH ORF, 2013) set forth in the campus Master Plan call for replacing the facility as part of the Center for Disease Research (CDR) North development on the existing Building 7 and 9 sites, although the NIH Office of Research Facilities advises that the location of the CDR is being reevaluated. There will be a continuing need to optimize animal research holding and core facilities across the IRP.

Data Science Infrastructure and High-Performance Computing

The recently published the *NIH Strategic Plan for Data Science* (NIH OD, 2018b) outlines the need to build a state-of-the-art data ecosystem able to support "big data" and high-performance computing (HPC) infrastructure. A new NIH chief data science officer position was developed to lead this critical strategic effort. Understanding basic biological mechanisms and clinical research focused on precision medicine depend on vast amounts of data. The storage and analysis of big data from interdisciplinary research efforts requires a sophisticated data infrastructure, a modernized data ecosystem, data management and analytics tools, a data-science workforce, as well as stewardship and sustainability (NIH, 2018b).

The NIH HPC group "plans, manages, and supports high-performance computing systems specifically for the intramural NIH community."[20] Examples include the following: "Biowulf, a 90,000+ processor Linux cluster; Helix, an interactive system for file transfer and management; Sciware, a set of applications for desktops; and Helixweb, which provides a number of web-based scientific tools."[21] The NIH HPC group supports computational applications in such fields as genomics, molecular and structural biology, mathematical and graphical analysis, and image analysis. There are several options for disk storage on the NIH HPC. There are no quotas, time limits, or other restrictions placed on the use of space on the NIH HPC.[22] The Biowulf HPC Environment is the only large-scale central computational resource dedicated to biomedical computing in the IRP. It is designed for general-purpose scientific computing—not dedicated to any single application type—and has dedicated staff with expertise in high-performance computing and computational biology to support research teams.

In response to the increasing data infrastructure needs of IRP investigators, Biowulf capabilities were expanded in FY 2014-FY 2018. This included modern architecture to provide both power and flexibility to IRP investigators, support data sharing and scientific collaborations through central data storage, and provide the ability to create an "NIH private cloud," as well as common application support and sufficient high availability to secure storage. These efforts have resulted in the NIH improved global ranking of HPC infrastructures from not being included in the top 500 in 2014 to being ranked 66 in 2017.

The immediate needs of smaller lab programs to support bioinformatics and computational biology have been met through limited renovation. This has provided high-end performance computing to "dry lab" teams who work in close proximity to "wet lab"-based teams where genomic sequencing and related biotechnology instrumentation is located. The programs were linked to the IC-specific HPC cluster or the campus Biowulf HPC.

Given the increased need for big data and HPC across the ICs, significant investments in the infrastructure outlined in the Strategic Plan will be required to support the IRP research enterprise. The current Biowulf "Buy-In" Model, in which nodes and storage are purchased by ICs but operated and maintained by the Center for Information Technology HPC staff, can be reviewed to ensure economies of scale across the IRP through consolidation while ensuring equal access for IRP investigators and trainees.

---

[19] Further information is available at the AAALAC International website at https://aaalac.org/.

[20] NIH, "BIOWULF: High Performance Computing at the NIH," https://hpc.nih.gov, accessed March 8, 2019.

[21] Ibid.

[22] Ibid.

One promising area is the current activity with respect to cloud computing for the entire NIH enterprise. Work with Google Cloud and Amazon Web Services through the Data Sciences strategy is moving along at a good rate, and plans are to use the cloud not simply for data storage but also for data calculations. The same amount of intensity is needed with respect to augmented and artificial intelligence across all of the NIH intramural programs.

Multi-Institute Facilities

The NIH CC links patient care with basic research discoveries and programs for the study of undiagnosed diseases and rare diseases and conditions. The vision of the Clinical Center is to lead the global effort in training today's investigators and discovering tomorrow's cures.[23] Since 1953, over 500,000 adult and pediatric research participants have come to the CC to enroll in clinical research studies not otherwise available. All patients are enrolled in research studies, and treatment at the CC is free of charge to the patients. In addition, housing facilities are available for research participants and their families on or in close proximity to the NIH campus. The CC sees about 10,000 new research participants a year. The CC is a mission-critical trans-NIH clinical research core facility. The Mark O. Hatfield Clinical Research Center (CRC) was opened in 2005 and houses adult and pediatric inpatient units, day hospitals, and research labs, and connects to the original Clinical Center building. The 870,000-square-foot CRC currently has 200 inpatient beds and 93 day-hospital stations. The development of first-in-human novel therapies requires state-of-the-art investigational pharmacy, dietary, laboratory, surgery, imaging, cellular therapy, immunotherapy, transfusion medicine, and pathology support services.

Approximately 1,200 credentialed physicians, dentists, and Ph.D. researchers; 620 nurses; and 450 allied health-care personnel work in patient care units and laboratories to support clinical study.[24] The collaborative environment of the NIH Clinical Center makes it possible for investigators to provide immediate testing and consult with a multidisciplinary team of scientists to come up with the best approach for diagnosing and treating patients. The freedoms of the NIH Clinical Center enable clinician-scientists to think out of the box and consider new approaches to treat diseases. The unique CC ecosystem allows for clinician scientists' research labs to be located in close proximity to the dedicated hospital wings and floors.

The NIH Clinical Center offers an extensive range of clinical research training including courses in pharmacology, principles and practice of clinical research, and bioethics.[25]

The John Edward Porter Neuroscience Research Center—delivered in two phases in 2004 and 2014—is a state-of-the-art 500,000-square-foot energy-efficient life science facility that brought together 800 scientists and 85 research labs from 10 ICs under one roof (Figure 3.5). Shared facilities include a peptide sequencing facility, a magnetic resonance imaging (MRI) suite, and a light imaging facility. The research programs span from basic to clinical neuroscience and focus on increasing understanding of typical and atypical brain development and function. This new facility provides an ecosystem that supports close proximity or interdisciplinary research teams and access to experts across disciplines for trainees. There is growing evidence that co-locating interdisciplinary research groups of investigators from different departments, institutes, and research disciplines can result in increased interactions between individual investigators, as well as discoveries/publications, grants/awards, and higher educational levels (Ravid et al., 2013).

---

[23] NIH, Clinical Center, "Office of Clinical Research Training and Medical Education," updated June 14, 2019, https://clinicalcenter.nih.gov/training/index.html.

[24] HHS, "HHS FY 2017 Budget in Brief–NIH," reviewed February 16, 2016, https://www.hhs.gov/about/budget/fy2017/budget-in-brief/nih/index.html; NIH Intramural Research Program, "What Is the IRP?" http://irp.nih.gov/about-us/what-is-the-irp.

[25] Further information is available at NIH Clinical Center, "Office of Clinical Research Training and Medical Education," updated June 14, 2019, https://clinicalcenter.nih.gov/training/training.html.

FIGURE 3.5 The National Institutes of Health (NIH) Porter Neuroscience Research Center, Bethesda, Maryland. SOURCE: NIH, "The John Edward Porter Neuroscience Research Center," reviewed July 21, 2015, https://www.nih.gov/about-nih/john-edward-porter-neuroscience-research-center.

NIH Library Reserve Workspace

The NIH Library Collaboration Pods are an example of how modern workspace environment pilot projects can be implemented to facilitate collaboration and provide access to critical shared resources. The pods can be used for small meetings to explore and use a variety of software programs and library resources. The library also provides access to HPC bioinformatics workspaces for high-throughput data analysis. Expanding these shared research environments strategically across the campus will provide the modern work environment required to support collaboration.

NIH Collaborative Forum

The NIH Human Resource Department's NIH Training Collaborative Forum brings together key stakeholders from the ICs training communities to foster inter-IC partnerships and information sharing. These efforts support the development of shared understanding and training standards in support of IC infrastructure integration.[26]

[26] NIH Office of Human Resources, "NIH Training Collaborative Forum," https://hr.nih.gov/training-center/resources/nih-training-collaborative-forum, accessed October 18, 2018.

Legacy of Scientific Accomplishments

The NIH IRP has made major contributions to the state of knowledge and practice, for the United States and the world. Nobel Prize-winning discoveries that were made at NIH include deciphering the genetic code, demonstrating that protein folding can be predicted from primary amino acid sequences, and discovering that "slow viruses" can cause degenerative neurological diseases. Five Nobel Prizes were awarded for research conducted at the NIH IRP, and an additional 22 NIH-trained investigators have been awarded the Nobel Prize. In addition, NIH IRP research has won 34 Lasker Awards (often termed the U.S. equivalent of the Nobel Prize), including 2 Lasker Awards in the past 7 years. Three IRP scientists have been awarded the National Medal of Science, which is bestowed by the President of the United States, and two NIH Directors have been awarded the Presidential Medal of Freedom.[27] As noted above, the NIH Biowulf HPC developed and used by IRP researchers was ranked 66 out of 500 most powerful such centers in the world.

The NIH IRP has also developed significant innovations in medical research and practice. Its core activities post-World War II resulted in the first formal review of clinical protocols, which became the model for the Institutional Research Board protocols throughout the United States and the world. NIH IRP also developed the first volunteer program to recruit "normal" (i.e., healthy) volunteers for control studies, and developed the processes, protocols, and means to deliver chemotherapy for cancer treatments. (Additional innovations are listed in Table 3.3.)

Many vaccines currently in use throughout the world are based on NIH IRP work, including vaccines for hepatitis A, Human Papilloma Virus, Rotavirus, and H. zoster (i.e., shingles). In addition, groundbreaking technologies developed at NIH IRP include the Coulter Counter (which is used to determine cellular constituents in the blood) and the spectrofluorometer (which is used to quantitatively determine fluorescence in chemical and biological samples). The software used to analyze MRI images was developed at NIH, as was the fPALM, a super-high-resolution cellular imaging microscope, which led to the award of the Nobel Prize to Dr. Eric Betzig (Gottesman and Baxevanix, 2017). Indeed, in 2017, Reuters ranked NIH/HHS first among the "Top 25 Global Innovators Government," ahead of France's Alternative Energies and Atomic Energy Commission[28] (CEA), and Germany's Fraunhofer Society[29] (see Ewalt, 2017).

TABLE 3.3 Examples of Significant NIH Intramural Research Program Innovations

First use of nitroglycerin for heart attack treatment
First enzyme replacement therapy (for Gaucher's Disease)[a]
First successful artificial mitral heart valve
First use of immunosuppressive therapy for nonmalignant diseases
First electronic medical information system for clinical research
First drugs for Acquired Immune Deficiency Syndrome
Development of blood lipids as biomarkers for cardiovascular disease
Development of fluoride gels to treat dental caries
Development of lithium to treat depression
Development of new imaging approaches for prostate cancer
Development of microbial genome sequencing in hospital epidemiology

[a] P.K. Mistry, G. Lopez, R. Schiffmann, N.W. Barton, N.J. Weinreb, and E. Sidransky, 2017, Gaucher disease: Progress and ongoing challenges, *Molecular Genetics and Metabolism* 120(1-2): 8-21.
SOURCE: Michael Gottesman, Deputy Director for Intramural Research, "The NIH Intramural Research Program is Recognized as a Premier Biomedical Research Facility," presentation to the committee on May 15, 2018.

[27] NIH Intramural Research Program, "Honors," https://irp.nih.gov/about-us/honors.
[28] Commissariat à l'énergie atomique et aux énergies alternatives.
[29] Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.

Partnerships

Selected Extramural and Intramural Research Program Collaborations

The NIH has a long history of establishing partnerships and networks to catalyze collaboration across HHS, other governmental organizations, and the extramural research community (NIH, 2018b). However, integration of the ICs' intramural resources and programs to foster collaborations has been a more recent strategic priority and is less well developed.

Table 3.4 gives examples of collaborations that have been initiated by NIH in order to advance its mission of improving human health and leveraging a valued national resource.

Training Programs

Training of the national and global biomedical research workforce is a primary focus of NIH and is stated in the organization's mission "to improve the health of the public through the support of biomedical research and the training of biomedical scientists" (Pool et al., 2016). To fulfill this mission, the Bethesda Campus's teaching, clinical practice, and research facilities must achieve an unprecedented level of success in fostering collaborative, multidisciplinary work in a highly efficient and adaptable environment while attracting the best clinicians, researchers, and students.

Training programs in biomedical sciences available to those working in the IRP span the continuum of education from undergraduate to postdoctoral training (see Figure 3.6). Over 5,000 basic scientists and clinicians from the United States and around the globe train at IRP. There is no other place in the world with a concentration of laboratories and individuals focused on improving the health of humankind.[30]

In fiscal year 2017, OIR educated 5,413 trainees (see Table 3.5). In addition to providing access to some of the world's leading research programs, the IRP along with the entire NIH community has developed unique training programs to address challenges such as diversity, global workforce capacity, and the shortage of physician researchers that threaten the biomedical workforce.

Office of Intramural Training and Education

The office coordinates training programs in biomedical science for all degree levels from high school summer internships to postdoctoral programs. The Graduate Partnership Program has formal institutional training partnership with academic institutions but also allows for individual agreements. Over 4,000 postdoctoral trainees come from across the United States and around the world to train at NIH. This unique and vibrant ecosystem serves as a foundation fostering future scientific collaboration as individuals progress in their careers. The Clinical Center provides yearlong research enrichment programs as well as short-term clinical electives for medical and dental students with the goal to attract the most creative research-oriented students to the Bethesda Campus. Many of the Office of Intramural Training and Education workshops and science skills tutorials are now available online to trainees outside of NIH.[31]

---

[30] NIH Office of Intramural Research, "Research Training," https://irp.nih.gov/research-training.

[31] NIH Office of Intramural Training and Education, "Training Programs in the Biomedical Sciences," https://www.training.nih.gov/programs, accessed November 9, 2018.

TABLE 3.4 Selected Extramural and Intramural Research Collaborations and Partnerships

Program	Purpose	Partnerships
NIH Clinical Center U01 Program	The program supports collaborations between extramural and intramural investigators by providing access to the unique resources of the Clinical Center to extramural researchers.	• Extramural investigators
National Cancer Institute	The Frederick Laboratory conducts research focused on the "most urgent and intractable problems in the biomedical sciences in cancer and AIDS drug development and first-in-human clinical trials, applications of nanotechnology in medicine, and rapid response to emerging threats of infectious disease."[a]	• Frederick Laboratory for Cancer Research at Frederick • National Interagency Confederation for Biological Research • Joint Design of Advanced Computational Solutions for Cancer • Department of Energy
NIH-NASA Biomedical Research Activities	In 2017, NIH and National Aeronautics and Space Administration[b] signed a Memorandum of Understanding to integrate the agencies research programs, share results, and improved understanding of human physiology and health.	• National Aeronautics and Space Administration
NIH—11 Leading Biopharmaceutical Companies PACT	"The National Institutes of Health and 11 leading biopharmaceutical companies today launched the Partnership for Accelerating Cancer Therapies (PACT), a five-year public-private research collaboration totaling $215 million as part of the Cancer Moonshot."[c]	• Biopharmaceutical Companies • Pharmaceutical Research and Manufacturers Association (PhRMA)
Regional Academic Collaboration		
National Institute on Aging (NIA)	The NIA IRP is located at multiple sites and is an example of physically extending the NIH ICs' reach beyond Bethesda Campus and integrating efforts with regional academic partners.	• Johns Hopkins University • Harbor Hospital in Baltimore
National Institute of Allergy and Infectious Disease (NIAID)	The goal of this collaboration is to develop and conduct clinical research studies focused on young children and find new treatments for allergic, immunologic, and infectious diseases while providing the best specialty care for this unique patient population. This regional partnership also provides training opportunities for medical and research professionals.	• Children's National Medical Center
John Edward Porter Neuroscience Research Center	The research programs span from basic and clinical neuroscience and focus on increasing understanding of typical and atypical brain development and function. This new facility provides an ecosystem that supports interdisciplinary research teams and access to experts across disciplines for trainees.	• 800 scientists and 85 research labs from 10 ICs under one roof.

[a] Frederick National Laboratory for Cancer Research, "About the Frederick National Laboratory for Cancer Research," https://frederick.cancer.gov/about/overview, accessed March 8, 2019.
[b] NIH and NASA, "History of NIH and NASA Collaborations," https://ncats.nih.gov/alliances/nasa/collaboration-history, accessed October 18, 2018.
[c] NIH, 2017, "NIH Partners with 11 Leading Biopharmaceutical Companies to Accelerate the Development of New Cancer Immunotherapy Strategies for More Patients," News release, October 12, https://www.nih.gov/news-events.
SOURCE: NIH Clinical Center, "Planning a Collaboration—Frequently Asked Questions," updated January 26, 2017, https://clinicalcenter.nih.gov/translational-research-resources/faq-1-planning.html-collaborations_3; AACR (2014); NIH NCI (2018a); EurekAlert! (2018); NIH National Institute on Aging, "About IRP," https://www.nia.nih.gov/research/labs/about-irp, accessed November 5, 2018; NIH (2017); Ravid et al. (2013).

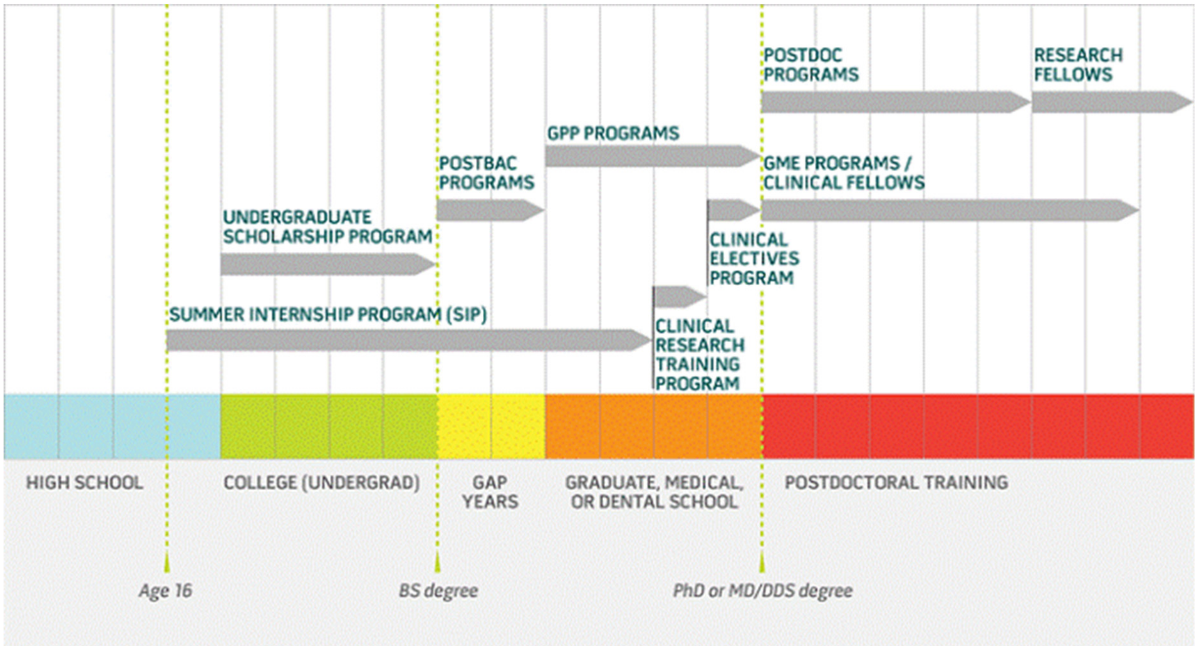


FIGURE 3.6 National Institutes of Health Intramural Research Program (IRP) Training Programs in Biomedical Science. SOURCE: NIH, Office of Intramural Training and Education.

TABLE 3.5 Number of Intramural Research Trainees in Fiscal Year 2017

Type	Number
Postdoctoral fellows	2,286
Graduate/medical/dental students	389
Postbaccalaureate trainees	1,309
Summer students	1,429

SOURCE: National Institutes of Health, Office of Intramural Research, "IRP Demographics," https://oir.nih.gov/sourcebook/personnel/irp-demographics, accessed January 30, 2019.

Diversity

Increasing the diversity of researchers and physician researchers is critical to the future of biomedical research in the United States, particularly as the share of the U.S. population comprised of underrepresented groups increases. In 2015, the *Long-Term IRP Planning Working Group Report* to the NIH ACD found that the IRP should lead in the development of new approaches to train and recruit a diverse biomedical workforce. The following training recommendations were recommended and adopted by the IRP (NIH ACD, 2015):

- Creation of a centralized program for recruitment, mentoring, and career development of postdoctoral fellows; and the
- Addition of a high-school summer enrichment program, and enhanced graduate and medical training programs.

The IRP implemented the Hi-STEP graduate summer program and developed a program to strengthen both extramural and intramural mentoring of young investigators. The number of full-time graduate students receiving funding from research assistantships from NIH in 2011 increased 60 percent to 65 percent in 10 years, emphasizing the importance of both formal and informal mentorship (Rockey, 2014).

To ensure the quality of the IRP training programs the IRP in collaboration with the National Academy of Sciences developed and implemented a training and mentoring guide to assist both trainees and mentors in outlining principles for training programs, criteria for good mentoring, and guidelines for the conduct of research. This guide assists individual laboratories, institutes, and centers in evaluating the success of their training programs and ensuring that programs are effective and current (NIH OD, 2008; Valantine, 2016).

Global Workforce Capacity

Chronic and infectious diseases continue to have an enormous toll on the world's population, and especially the poorest populations. To combat these health issues, substantial investments are being made in the development of new health technologies. While many of the interventions are safe and effective, they cannot be implemented broadly due to logistical, cultural, financial, and other barriers. Addressing these barriers will require that trained researchers can most effectively translate research findings into practice. NIH supports international research training of over 5,000 researchers from low- to middle-income countries. Every year, NIH trains more than 2,500 foreign scientists in its intramural laboratories.[32]

Physician Scientists

Survey data from the American Medical Association show a decline of 5.5 percent in the number of physicians conducting research between 2003 and 2012. Over the same time span, the demographics of NIH-funded principal investigators have changed; when viewed by decade of life, it is apparent that the proportion of individuals in their 60s and 70s has increased and those under 60 declined (see Figure 3.7).

Although NIH has been concerned about the aging of the biomedical workforce, the need for younger physician-scientists is even more pressing (Kaiser, 2014).

The NIH's Clinical Center offers a unique environment for training physician-scientists with hospital facilities that house both basic and clinical research in one location. Clinical research training courses offered at NIH and at remote sites have trained over 18,000 students since 1995. The annual Clinical Investigator Student Trainee Forum hosted by the CC provides an intensive educational experience for medical and dental students. The Clinical Center also holds a clinical management course on campus to expose experienced investors to the skills needed to run a clinical research program.[33]

In order to be able to develop and implement unique training programs, IRP must maintain and enhance both the culture and facilities needed for outstanding contemporary basic laboratory and clinical research and training. The campus's teaching, clinical practice, and research facilities must address existing needs and the emerging biomedical trends as identified in Chapter 2. Facilities must accommodate advances in technology, simulation, interdisciplinary research, and clinical care and maintain the flexibility to accommodate ongoing changes in the delivery of education and training of healthcare professionals. Amenities such as hoteling workspaces, fitness/wellness centers, and green spaces that enhance the campus's work environment are also needed if the IRP is to continue to attract excellent researchers, clinicians, and trainees.

---

[32] NIH, "Building Global Health Research Capacity," Fact Sheet, updated June 30, 2018, https://report.nih.gov/NIHfactsheets/ViewFactSheet.aspx?csid=74.

[33] NIH, "Clinical Research Training at the NIH Clinical Center," Fact Sheet, updated June 30, 2018, https://report.nih.gov/nihfactsheets/ViewFactSheet.aspx?csid=82.

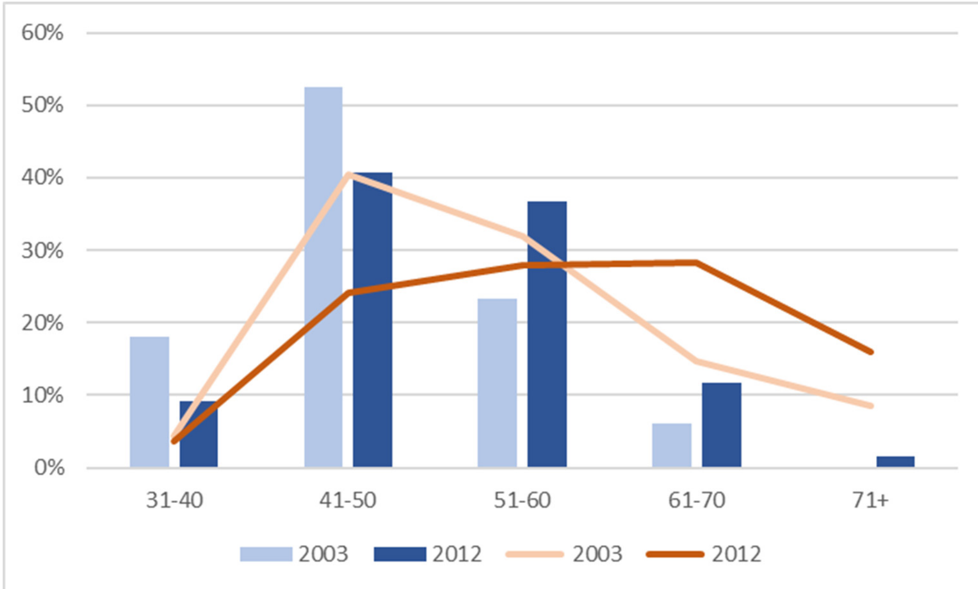


FIGURE 3.7 Physicians in medical research. The lines show the percentage of physicians by decade of age who indicated that they were primarily in medical education or medical research. From the American Medical Association Physician Masterfile Annual Year-End Snapshots. The bars show physicians (both with and without Ph.D.s) who received NIH R01 grants. SOURCE: Chapter 3 Main Data and Table A5-2 in National Institutes of Health, "Appendix IV: Physician-Scientists Workforce Data," in *Physician-Scientist Workforce (PSW) Report 2014*, https://report.nih.gov/workforce/psw/index.aspx.

4

Current Condition

This chapter will describe the evolution and current state of the National Institutes of Health Bethesda Campus (NIH-BC), including the purpose and size of its buildings, their defined uses and current condition for their intended uses, and a recent history of investment for specific purposes and sustaining needs.

INFRASTRUCTURE IN SUPPORT OF SCIENTIFIC ACTIVITIES AT NIH-BC

Overview

The NIH Bethesda Campus currently utilizes facilities dating back to 1923. Of the nearly 13.5 million net assignable square feet (SF) of research and administration building space, one-half requires renovation at levels ranging from complete demolition (1.2 million SF); substantial improvement (3.5 million SF); and safety code required remodeling (2 million SF). The underground utilities that service 98 buildings need maintenance and upgrades to prevent critical disruptions of water, heat, electricity, and communications.

Over the past nearly 100 years, the campus has seen many changes. Starting with a few small buildings originally, the campus now includes approximately 98 buildings totaling 13.5 million square SF of facilities and 20 miles of underground utilities having a current replacement value of $7.5 billion. These facilities are located on a 310-acre mixed-use campus that includes roadways, walkways, parking structures, and significant green spaces to buffer the campus from surrounding neighbors.

Sixteen of the campus facilities are in such a deteriorated condition that they are recommended for demolition. These facilities account for approximately 1.2 million SF, of which approximately 40 percent is laboratory and 60 percent administrative space. Another 3.5 million SF are in need of substantive improvement, maintenance, and repair to perform their defined service. Another 2 million SF are in need of attention to improve comfort and power systems, weather tightness, and code and life safety issues. The balance of 6.7 million SF, about half of the total square footage of the campus's built environment, are in reasonably serviceable condition and are fit for their assigned uses. The 20 miles of underground utilities and their sources have an array of problems needing significant attention to sustain and support the 98 buildings they serve.

Over the last two decades, NIH has expended slightly over $4.1 billion (Figure 4.1) from its Buildings and Facilities (B&F) appropriation on new, renovated, and updated buildings and safety and support of its built environment. Approximately $2.3 billion of that is for construction-related activity. These activities include constructing new buildings; reconfiguring existing spaces to accommodate new services; repairing existing space and structure, including safety, power, and comfort systems; and restoring deteriorating interior and exterior structural features. The planning and implementation of this volume of work has been overseen by a qualified internal team that is required to justify and prioritize needs, advocate for funding, and execute structural changes around fully operational laboratories in a highly regulated and sensitive patient and animal care activity.

Since 1998, significant appropriations have contributed to the campus and its mission. Figure 4.1 shows the use of the funding and illustrates that most of the funding came from a few large special appropriations that were dedicated to major construction projects. These projects are briefly described here:

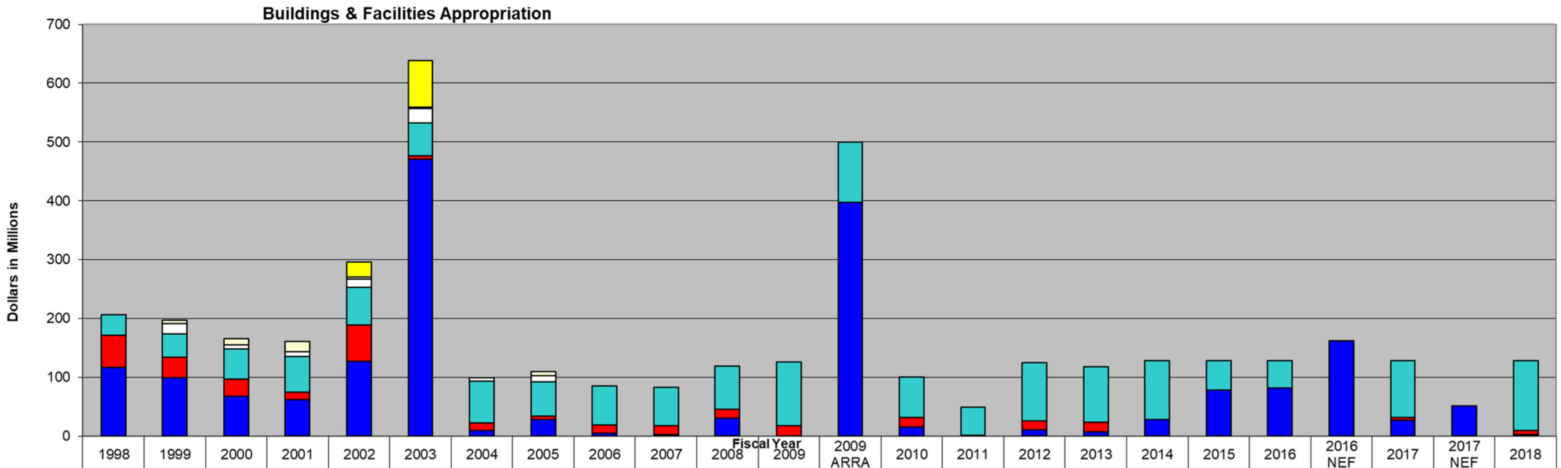
- The Dale and Betty Bumpers Vaccine Research Center was completed in 2000. This 140,000 SF lab and research building is dedicated to vaccine research; its primary mission has been HIV/AIDS research.
- In 2001, the Louis Stokes Laboratory was completed. This building introduced the concept of research "neighborhoods" to the campus. This 6-story, 565,459 SF building provides 250,000 SF of state-of-the-art laboratory, office, and conference facilities for scientists from nine NIH institutes.
- The Mark O. Hatfield Clinical Research Center was completed in 2004 and added 620,000 SF of inpatient hospital treatment space and day-hospital space and 240,000 SF of laboratory space. Along with the clinical space, two family care facilities were provided.
- The original Porter Neuroscience Research Center was completed in 2004 and provided 600,000 SF of research space housing for personnel from seven different institutes.
- In 2007, the C.W. Bill Young Center for Biodefense and Emerging Infectious Diseases opened with 84,000 SF of research building and parking facilities for over 2000 vehicles.[1]
- The American Recovery and Reinvestment Act (ARRA) of 2009 provided $500 million for B&F expansion and repair of NIH facilities. This allowed for phase II of the Porter Neuroscience Research Center to be constructed. This added 306,000 SF of integrated laboratory and research space when completed in 2014.

Since 2000, just under 3 million SF of laboratories have been added to the campus. This accounts for 45 percent of all lab space on campus. During this time, several smaller buildings were constructed to house families, support operations, improve security, and improve energy efficiency, sustainability, and utility distribution, including the following:

- The Center for Information Technology Data Center, which was upgraded to increase data storage and transmission speed, as well as weather and disruption sustainability.
- A Thermal Energy Storage system program, storing water that is chilled after-hours, was commissioned in 2018 to significantly enhance the efficiency and reliability of the Central Utility Plant.
- The E and F wings of the original Building 10, about 500,000 SF of hospital converted to lab space use.

---

[1] Part of Project Bioshield. This included the following monies for NIH buildings: BSL 4 facilities at RML (NIAID) $70 million and Frederick (NIAID) $104 million; Building 33 Bethesda (NIAID) $186 million (D. Cushing, NIH Office of Research Facilities, communication to M. Offutt, National Academies of Sciences, Engineering, and Medicine, August 20, 2018).



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 ARRA	2010	2011	2012	2013	2014	2015	2016	2016 NEF	2017	2017 NEF	2018
Security	0	0	0	0	25	80	0	0	0	0	0	0		0										
Equip/Systems/Enabling	0	6.4	10	17.6	3.6	2	0	7	0	0	0	0		0										
Renovation	0	17	7.2	8.2	14.1	24.1	5.5	10.8	0	0	0	0		0										
Repair & Improvements	35	40	50.7	60.1	64.6	55.8	70.5	58.4	66.4	65.9	73	107.6	103.1	68	48.8	98.9	94.5	100	50.7	46.65		96.9		118.9
Essen. Safety & Reg. Compliance	54.8	34.9	29.2	13	61.6	6.2	13.5	6	14	14.5	15.5	17.5		16	1.1	16	16.25					4.5		7
Construction	116.8	99.1	68.3	62	127	470.6	9.5	28.1	5.2	3.2	30.5	0.5	396.9	16	0	10.4	7.35	28.6	78.2	82.2	162.1	27	51.8	3

Construction · Essen. Safety & Reg. Compliance · Repair & Improvements · Renovation · Equip/Systems/Enabling · Security

FIGURE 4.1 Buildings and Facilities funding, 1998 to 2018. SOURCE: National Institutes of Health, Office of Research Facilities.

Funding for Capital Projects

NIH funding is appropriated each fiscal year through the appropriations process. The budget formulation process occurs each June through December, in which the Department of Health and Human Services (HHS) prepares a budget—as do the other agencies and departments—in consultation with and pursuant to circulars and procedures of the Office of Management and Budget. The resulting President's Budget Request is submitted to Congress in February or later of the following year. Thereafter, HHS develops Congressional Justifications, which include details of the NIH request for B&F funds 2 years into the future.

Funding for capital projects comes from a number of sources, including the B&F line item in the Congressional appropriation noted above; a nonrecurring expense fund (NEF), from the HHS; and one-time appropriations. (The funding appropriated for NIH does not ring-fence or otherwise separate capital budget dollars from operating budget dollars.) NIH is further able to direct monies from operating funds of individual institutes (using what is known as the special authority, a reference to its origin in the appropriations bills) or from centrally administered funds such as the Capital Improvement Fund using deposits from the institutes and centers' (ICs) appropriated funds.

The B&F line item has been constant for many years, at roughly $120 million (see Figure 4.1). These funds are intended to support the mission through facilities maintenance and repair. The NEF competes with the needs of other agencies within HHS. Special one-time appropriations come from Congress for various reasons or in support of a defined need, including, most recently the ARRA funds in 2009.

SPACE UTILIZATION AT NIH-BC

The 13.5 million SF on the Bethesda Campus (see Figure 4.2) can be broken down into three main asset categories: laboratories (which includes clinical space),[2] administration, and animal care. The remaining space in the 98 buildings comprises support facilities for utilities/industrial uses, parking, housing, warehouses, and so on.

To accommodate a growing residential community around its boundaries over time, as well as emerging federal regulations on security standoffs from boundary perimeters, the Bethesda Campus instituted a buffer zone of 67 acres (22 percent of total acreage) (see Table 4.1). An additional 112 acres (36 percent of total acreage) comprise open space, including gardens and outside seating areas, and 54 acres (17 percent of total acreage) are dedicated for roads, walkways, and service areas. Buildings currently occupy 49 acres (16 percent of total acreage), and a combination of parking facilities occupy the remaining 9 percent of acreage.

The Bethesda Campus consists of almost 11 million net assignable square feet (NASF) within its built facilities. NIH also owns approximately 2.5 million NASF on other campuses, including Fort Detrick, Poolesville, and the Rocky Mountain Laboratory (Hamilton, Montana) and Research Triangle Park (North Carolina) campuses. The building commons areas (such as lobbies, main corridors, restrooms, and building support areas) comprise the majority of the NASF at 54 percent (see Table 4.2). If the building common areas are excluded, over 80 percent of the non-commons NASF is allocated to a single institute or center, and 15 percent of the non-commons NASF is held by the Office of Research Facilities (ORF) or the Office of Research Services. Approximately 48,000 NASF (1 percent of non-commons NASF) is space shared among two or more ICs.

Excluding the building commons NASF, slightly over one-third of the assigned space on the Bethesda Campus (36 percent) is categorized as laboratory space, 27 percent as administrative space, 15 percent as clinical space, and 9 percent as animal care space (see Table 4.3). An additional 13 percent is categorized as "other," and includes facilities such as the Children's Inn at NIH (a residential facility on the campus).

[2] The Federal Real Property Council categories are such that investigational space such as the Clinical Center is counted as "Laboratories."

FIGURE 4.2 National Institutes of Health Bethesda Campus. SOURCE: NIH Office of Research Facilities.

TABLE 4.1 NIH Bethesda Campus Land Use Allocation

Land Use	Acres	% of Total
Open space	112	36
Buffer zone	67	22
Roads/walkways/service areas	54	17
Buildings	49	16
Parking	28	9
Total	310	100

SOURCE: HHS and NIH, 2013, *2013 Comprehensive Master Plan—Bethesda Campus*, June 14, p. 4-3.

TABLE 4.2 NIH Bethesda Campus Building Use Allocation

Organizational Unit	Net Assignable Square Feet (NASF)	Fraction of Total (%)	Fraction of NASF[a] (%)
Building commons	5,873,889	54	
IC single unit	4,215,384	39	84
ORS/ORF	738,577	7	15
IC shared	48,553	0	1
Total	10,876,403	100	100

[a] Exclusive of building commons.
NOTE: Based on rent model dated 10-16-2017. IC, institute or center; ORS, Office of Research Services; ORF, Office of Research Facilities.
SOURCE: NIH Office of Research Facilities, "Questions from NAS—Part 3," via e-mail, June 14, 2018.

TABLE 4.3 NIH Bethesda Campus Assigned Space (Excluding Commons) by Four Main Asset Categories

Occupancy Category	Net Assigned Square Feet	Fraction of Total (%)
Laboratory	1,791,301	36
Administrative	1,365,659	27
Clinical	764,295	15
Animal	428,580	9
Other	652,268	13
Total	5,002,103	100

SOURCE: NIH Office of Research Facilities, "Questions from NAS—Part 3," via e-mail, June 14, 2018.

The ICs and the administrative units, the latter situated within the Office of the Director, and nonfederal asset holders such as the Foundation and the Children's Inn have been assigned significant amounts of square footage categorized as "administrative." Eleven organizational units occupy 38 percent of all administrative space, and 33 percent of all "other" space occupies approximately 15 percent of the assigned space on the Bethesda Campus (734,021 SF). (These organizational units do not occupy other categories of space usage. Please see Appendix G for details.) In addition, approximately 7 percent of the assignable square footage (331,561 SF) is currently vacant (e.g., awaiting renovation or demolition), representing 35 percent of the "other" space, 12 percent of the clinical space, and 10 percent of the laboratory space (see Table 4.4). The ORS and ORF occupy 14 percent of assignable space (738,577 SF) in all categories.

The various NIH ICs—aside from those mentioned in Table 4.4—occupy the remaining 3.2 million SF of assignable space across the Bethesda Campus (see Appendix G). The Clinical Center occupies 86 percent of all clinical assignable space on the campus. The National Eye Institute, National Institute of Neurological Disorders and Stroke, and National Institute of Allergy and Infectious Diseases (NIAID) each occupy 15 percent of the total animal assignable space. NIAID also occupies 12 percent of the total laboratory assignable space, while the National Cancer Institute occupies 20 percent of total laboratory space, 9 percent of all animal space, and 7 percent of all administrative space (see Figure 4.3).

TABLE 4.4 NIH Bethesda Campus Assigned Space by Occupancy: Administrative Units, Institutes or Centers (ICs), and Vacant

Unit	Administrative	Animal	Clinical	Laboratory	Other	Total	Percentage of all NASF (%)[a]
ICs without wet laboratory, animal, or clinical space[b]	382,600	—	—	—	135,529	518,130	10
Administrative[c]	138,642	—	—	—	77,249	215,891	4
Vacant space	30,934	5,690	91,032	186,491	17,415	331,561	7
Office of Research Facilities	115,328	0	597	8,979	56,547	181,451	3
Office of Research Services	133,248	146,164	0	19,312	258,401	557,125	11
Subtotal	800,753	151,854	91,629	214,783	545,141	1,804,159	36
Percentage of Total by Category	59	35	12	12	84		

[a] As a fraction of all assignable square footage (5,002,103 NASF) listed in Table 4.3.
[b] Includes Center for Information Technology, Center for Scientific Research, National Center for Advancing Translational Sciences, Fogarty International Center, National Institute of General Medical Sciences, and National Library of Medicine.
[c] Includes Foundation for the NIH; Office of Human Resources, Foundation for Advanced Education in the Sciences, Children's Inn at NIH, and Office of the Director.
NOTE: May not add due to rounding. NASF, net assignable square feet.
SOURCE: NIH Office of Research Facilities, "Questions from NAS—Part 3," via e-mail, June 14, 2018.

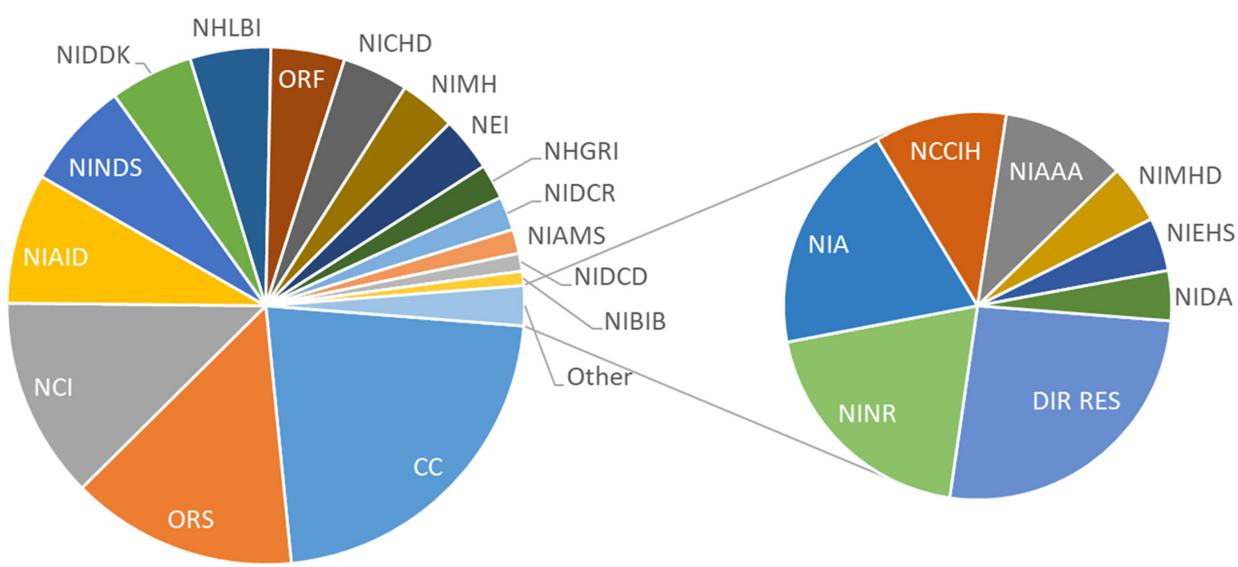


FIGURE 4.3 NIH Bethesda Campus assigned space by institute and center (excluding units with no space assigned—falling in the categories of wet lab, clinical research, or vivarium). SOURCE: Figure drawn by committee with NIH data.

CURRENT CONDITIONS OF IRP FACILITIES AT NIH-BC

IRP Facilities Are a Mix of Recently Built and Past-Their-Prime Buildings

The Master Plan (NIH ORF, 2013) identifies 16 buildings scheduled for demolition. Of these, 12 are predominantly for laboratory use. These buildings were built in the 1940s and 1950s. Their condition, shape, and utility render them more costly to renovate than to replace. Specifically, the floor-to-floor height of the existing structures is insufficient to support the significant duct work and ventilation systems and other power, water, and data needs. This accounts for 477,457 SF (7.5 percent) of total laboratory space on campus. This specifically includes a major portion of the animal facilities, a major contributor to the testing and research done in early clinical trials.

The other 4 buildings in this list are primarily administrative space and account for 743,482 SF (43.5 percent) of available administrative space.

Since 2000, 2,900,000 SF feet of laboratory space have been added to the campus. This accounts for 45 percent of total lab space on campus. An additional 982,000 SF of parking structure, housing, and support facilities have been added. This represents approximately 28 percent of the campus. Said another way, 72 percent of the campus is over 20 years old.

An additional 1.1 million SF of space have seen significant renovation or reuse. Notably, 765,911 SF of laboratory space have been renovated or reconfigured to support benchtop science. An example of this is the E and F wings of Building 10, which were converted from hospital function to lab function.

NIH BMAR and Facility Condition Index and the Degree to Which Maintenance Backlog Is or Is Not Part of the Decision Making Process

NIH's Backlog of Maintenance and Repair (BMAR) is developed each year under contract with an outside consultant, who maintains an extensive database of all building system conditions and life cycle cost data to ensure that when each component has reached the end of useful life, the renewable costs are generated automatically into the BMAR calculations. The BMAR is updated each October based on the contractor's database and adjusted according to a review of any repairs and renovations that occurred since the previous year. Additionally, each April, an escalation factor is added to the BMAR totals, ranging between 2 and 4 percent. The process for determining each year's specific escalation factor was not provided to the committee, but the amounts seem reasonable.

NIH also incurs costs that do not effectively reduce the BMAR. These include the following: (1) emergency repairs (often due to the age of the facilities); (2) change orders—for unforeseen conditions discovered during renovation and specific aging systems that are impacted by attaching upgraded systems; (3) environmental—the age of the facilities also contributes to significant costs for remediating hazardous materials such as asbestos, lead, and laboratory contaminants such as mercury; and (4) mission support—NIH often needs to conduct repairs and improvements to support new scientific equipment. Combined, these factors often consume a large portion of funding, leaving the balance available to reduce BMAR. In the past, NIH tracked only the Condition Index (CI) and BMAR associated with buildings; recently, it began including infrastructure in the Central Utility Plant (CUP, Building 11 in Figure 4.2) and horizontal site infrastructure (chilled water, steam, fire protection, and electrical power distribution) in those calculations (NIH, 2018a).

The BMAR Reduction Plan for the campus is reported to include the following (NIH, 2018a):

- A combination of capital projects that are already funded but not yet calculated as a reduction;

- Planned capital projects that are developed and shown on the 5-year B&F Plan;[3]
- Capital projects that need to be planned and funded based on their level of CI, type of facility, and level of risk;
- Mothballed facilities that require modest investment to maintain; and
- Targeted projects to existing facilities for recurring large maintenance issues, emergency issues, and major repairs (based on the 5-year B&F Plan for repair and improvements).

The BMAR is used to create the Asset CI defined by the condition assessment contractor as follows:[4]

$$CI = \left[1 - \frac{\text{cost of existing requirements (due in 1 year or before)}}{\text{current systems replacement value}}\right] \times 100$$

The ORF provided the committee with a listing of all facilities managed at the various NIH properties. This facility list was filtered to include only the Bethesda Campus and is included as Appendix F. The Bethesda facility list includes the facility number, use, year constructed, size, replacement value, BMAR, and condition index. The BMAR is $1.3 billion (on a replacement value for those same facilities and infrastructure of $7.5 billion). The average Condition Index of NIH buildings is 83.3, which is among the lowest in the federal government (see Figure 4.4). As a reference, the International Facility Management Association CI index rating system would consider a rating of 83.3 as "poor." Figure 4.4 shows the relative comparison of the NIH CI compared to many other federal agencies.

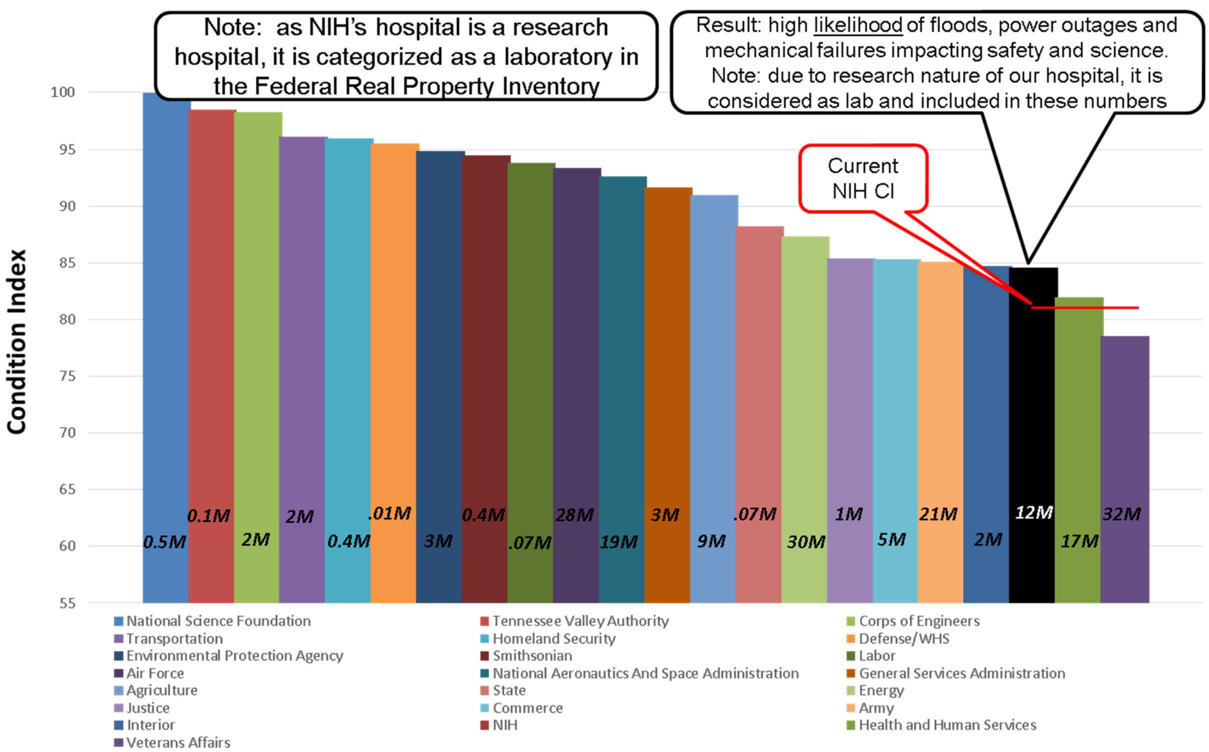


FIGURE 4.4 Condition Index (CI; aggregate) of various federal agencies and departments. SOURCE: NIH, 2018, *Backlog of Maintenance and Repair (BMAR) Reduction Plan*, Bethesda, Md., January 5, 2018.

[3] The 5-year B&F Plan is the result of scoring proposals for program impact and facility impact and classifying them into three levels of relative priority for execution (D. Cushing, NIH Office of Research Facilities, "Capital Projects: On Deck, Shovel Ready & Emerging," presentation to the committee March 20, 2018).

[4] Raymond Dufresne, Accruent, LLC, "Benchmarking NIH Assets," presentation to the committee, August 8, 2018.

TABLE 4.5 Facilities of NIH Bethesda Campus Sorted by Condition Index

Rating[a]	Score	No. of Facilities	Total area (square feet)	Replacement Value ($)	BMAR ($)	Average Facility Age (years)	Average CI
Good	100-95	19	3,657,835	1,792,794,182	30,243,802	37	98.3
Fair	94-90	21	3,063,511	1,585,947,565	114,498,944	44	92.8
Poor	89-70	38	5,311,983	3,586,192,920	795,842,580	59	77.6
Critical	< 70	20	1,450,722	577,476,558	310,595,055	61	46.2

[a] International Facility Management Association condition categories.
NOTE: BMAR, Backlog of Maintenance and Repair; CI, Condition Index.

TABLE 4.6 Facilities of NIH Bethesda Campus Sorted by Condition Index, with 16 Buildings Demolished per the 2013 Master Plan

Rating[a]	Score	No. of Facilities	Total area (square feet)	Replacement Value ($)	BMAR ($)	Average Facility Age (years)	Average CI
Good	100-95	18	3,652,659	1,787,953,151	30,146,177	35	98.3
Fair	94-90	19	2,889,118	1,422,840,559	103,219,030	42	92.7
Poor	89-70	30	5,110,382	3,439,844,774	770,467,982	58	77.6
Critical	< 70	15	606,437	271,742,056	121,800,114	60	55.2

[a] International Facility Management Association condition categories.
NOTE: BMAR, Backlog of Maintenance and Repair; CI, Condition Index.

Table 4.5 categorizes facilities by CI; the committee developed this table from the data provided by the ORF. Of the 98 facilities on the Bethesda Campus, 58 have a CI rating of poor (<90) or critical (<70). Half of the campus's total SF is rated at poor or critical and has an average facility age of 59 years for facilities rated poor and 61 years for those rated critical. This compares to an average age of 37 years and 44 years for the facilities rated good or fair, respectively. NIH reports that its goal is to raise the CI above 90 for all campus facilities. Table 4.6 shows how many facilities would be each CI category were the 16 facilities slated for demolition in the Master Plan to be removed.

Risk to Research and Patient Care Created by Outages and Disruptions

The NIH presented information[5] that provided the current project score process, called the B&F Project Prioritization Model for fiscal year (FY) 2019-2023 and based on a total possible score of 1,000. The scoring process assigns a potential 222 points out of the 1,000 total, or 22.2 percent of the score to the building systems' risk of failure impacting life safety and critical mission functions. The Facilities Working Group (FWG) subjectively scores the risk for each project. There is no campus-wide risk assessment process that quantifies the impacts to research and patient care for each facility and facility system. This is discussed further in Chapter 5.

The NIH facilities at the Bethesda Campus have experienced various system failures in the past several years. During the committee's inspection of various buildings accompanied by members of the NIH ORF staff described several failures of plumbing distribution systems that resulted in flooding to laboratories and operating rooms. NIH did not provide any comprehensive historical reporting (e.g., frequency, system,

[5] D. Cushing, NIH Office of Research Facilities, "Projects Selection and Execution 2018 B&F Proposed Line Item Projects for Prioritization (FY 2019-2023)," presentation to the committee, May 15, 2018.

type of failure, and resulting impacts) of these failures from the Computerized Maintenance Management System such as might support a more comprehensive risk assessment process.

Portions of a presentation[6] included information on the Building 10 Complex. This was the only example provided of using condition assessment data to develop the risk assessment. Data for the 2011 facilities condition assessment rated the mechanical systems, the electrical systems, and the functionality and quantity of space. There were no research or patient care impacts identified in this presentation.

Finding: NIH does not have a formalized risk assessment process across the facilities portfolio that measures and ranks facilities or facility systems from historical operations and maintenance records. The facility condition assessment process generates the BMAR, which identifies the associated level of risk to personnel, patients, and research created by potential outages and disruptions of facility systems.

Building Process and Monies Available or Used

The B&F account is one of 27 accounts for which the dollar amount is controlled by Congress (see the section "Funding for Capital Projects," above). B&F funds are 5-year appropriations, meaning that they can be carried over into subsequent fiscal years, something that is critically important for acquisition of capital projects. Funds are allotted per quarter based on requests typically weighted to second and third quarter (Q2 and Q3). FY 2018 funding was $128 million, roughly consistent with immediate past years.

The FY 2019 B&F funding request was $200 million; this amount was appropriated. Complementing the B&F account, episodic one-time increases have occurred historically based on specific events such as Biodefense (2003) and ARRA (2009) (see Figure 4.1, above).[7] Congress typically appropriates the amount requested for the B&F account in the President's budget.

The so-called special authority is revisited from time to time. Originally, as part of the NIH FY 2007 Appropriation Act,[8] Congress authorized NIH to spend IC operating funds of up to $2,500,000 per project to cover costs associated with altering, repairing, or improving NIH facilities. A similar provision was included in the FY 2009 President's budget request, limiting the total IC operating funds expenditures for renovations, alterations, and repairs to no more than $35,000,000 for the year. From 2008 to 2011, ORF spent an average of $21.7 million per year of IC funds on repairs and improvements.[9] A majority of these funds have been spent on specific needs and requests by individual ICs for their spaces. Each year, specific capital projects are presented to the NIH Office of the Director and to the department-level (HHS) entities concerned with facilities and finance for consideration for approval and funding through Facility Project Approval Agreements.

The FY 2012 Omnibus Appropriation Act, Section 216, changed the ceiling on the amount of funds appropriated to the ICs that could be used for alteration, repair, or improvement of facilities to $45,000,000, not to exceed $3,500,000 per project. From 2012 to 2018, ORF spent an average of $37.2 million per year of IC funds on repairs and improvements.[10] NIH describes the potential uses of such funds "that count against the ceiling" as follows:

---

[6] D. Cushing, NIH Office of Research Facilities, "Capital Projects on Deck, Shovel Ready & Emerging," presentation to the committee, March 20, 2018.

[7] D. Cushing, NIH Office of Research Facilities, "Annual Budgets: Buildings and Facilities Maintenance and Process," presentation to the committee, March 20, 2018.

[8] Fiscal Year Consolidated Appropriations Act (Pub. Law 110-161), Division G, Section 223.

[9] Stephanie Hixson, NIH Office of Research Facilities, communication to Martin Offutt, National Academies of Sciences, Engineering, and Medicine, February 8, 2019.

[10] Ibid.

- Renovations to all office, laboratory, clinical, animal, research, or support space that involve new drywall or masonry partitions, installed doors, ceilings, lighting, and permanent flooring or the reconfiguration of such;
- Alterations that change the use or function of existing program space (i.e., office-to-lab, lab-to-office, lab-to-animal room, etc.);
- Infrastructure repair work that is directly impacted by IC renovations or alterations; and
- Architect and Engineer design and inspection costs.

Examples of project-related costs that do not count against the $3.5 million ceiling include the following:

- Pre-project planning and pre-design studies (studies and Program of Requirements)
- Fee for Service work
- Furniture or furnishings
- Carpet and window coverings
- Casework and counter tops
- Special purpose equipment such as IC scientific instrumentation, CT scanners and work directly incident to such.[11]

Congress authorized use of the NEF for capital acquisitions related to information technology (IT) and facilities infrastructure. ORF has explored and requested the use of NEF for the past 4 years with success in FY 2015 ($10 million), FY 2016 ($162 million), and FY 2017 ($52 million), as illustrated in Figure 4.5. No funds were made available in FY 2018.

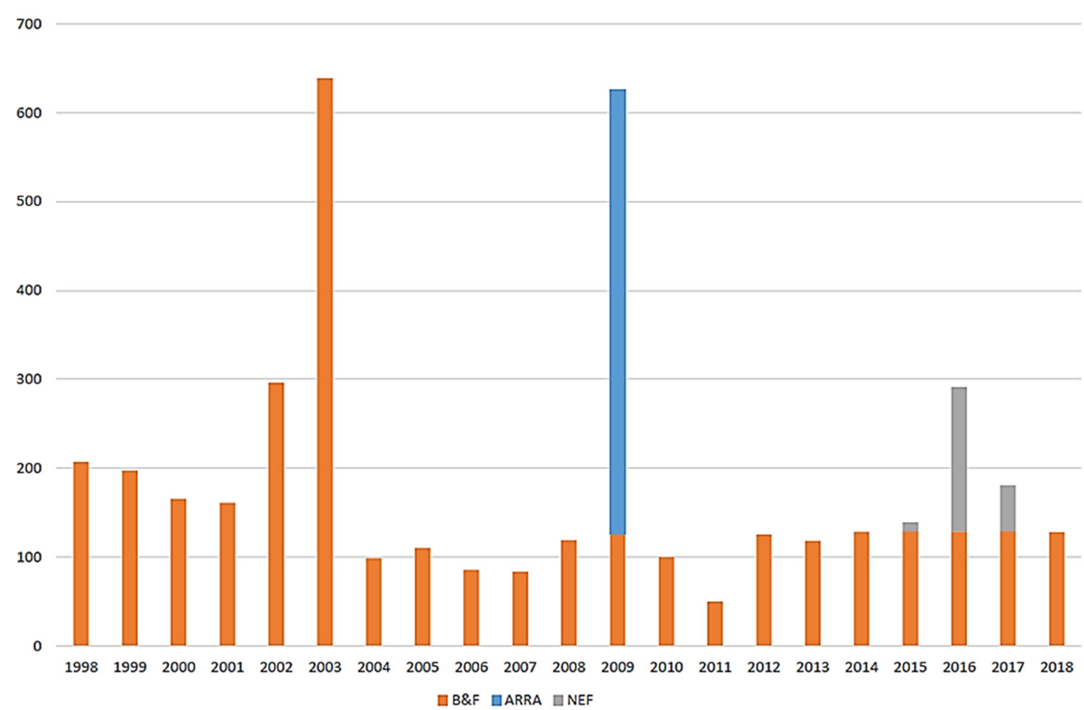


FIGURE 4.5 NIH funding levels for facilities (1988-2018). This includes the appropriated Buildings and Facilities (B&F) account, the American Recovery and Reinvestment Act (ARRA) of 2009, and funds made available from HHS through the nonrecurring expense funds (NEF). SOURCE: NIH Office of Research Facilities.

[11] NIH Office of Research Facilities, "Funding and Budget for Construction, Alterations and Renovations," March 30, https://www.orf.od.nih.gov/Construction/Funding/Pages/default.aspx.

TABLE 4.7 NIH-Bethesda Facilities Maintenance Budget Fiscal Year 2017

	2017 ($)	2018 ($)
Operations	60,344,439	71,732,713
Maintenance	45,295,927	42,105,421
Total	105,640,366	113,838,134

SOURCE: Stephanie Hixson, NIH Office of Research Facilities, communication to Martin Offutt, National Academies of Sciences, Engineering, and Medicine, May 9, 2019.

The Division of Facilities, Operations, and Maintenance (DFOM) is responsible for the safe, efficient, and effective operation and maintenance of NIH real property. The annual budget originates from the ICs' appropriated funds in the following manner: ICs are charged rent based on the NASF plus common areas for laboratory space ($42 per square foot [/SF]), administrative space ($22/SF), and animal facility ($34.61/SF). These funds are used to fund the ORF operating budget, which includes facilities maintenance. The FY 2017 DFOM annual budget (Table 4.7) was $105.6 million for general operations and maintenance, minor repairs and replace in kind (not to exceed $75,000 each), and maintenance service contracts (there are approximately 70 such contracts for janitorial, elevators, building automation, grounds maintenance, emergency generators, air balancing, and other services including labor and materials). For FY 2018, the operation and maintenance obligations for Maryland campuses were respectively $71.7 million and $42.1 million, for a total of $113.8 million.[12] Operations would include, for example, operation of Central Utility Plant; grounds maintenance, including snow removal; and custodial services.

Facility managers for each building manage the day-to-day work associated with operating a building. Branch chiefs are responsible for service areas such as Building 10, the remaining Bethesda Campus, other Maryland campuses (e.g., Bayside in Baltimore) and those in Research Triangle Park (NIEHS) and Rocky Mountain Laboratory (NIAID). A Project Contract Team can do specific project work if the project is valued under $75,000 or in emergencies. DFOM can do in-house engineering design for work that requires a quick turnaround such as during emergencies. All other work requiring engineering that is nonemergency and over $75,000 must be transferred to Design and Construction for B&F funding.

Project Dashboard

NIH shared its project needs in a document titled "400 Project Dashboard,"[13] outlining projects for maintenance and repair. This list includes 440 lines of project descriptions and estimates of cost, and it categorizes the projects in a number of ways. The list is generated by the staff who are responsible for the maintenance and upkeep of the facilities and in some cases the design and construction planning team (see Table 4.8).

The committee determined that a number of the categories in Table 4.8 would fall under the heading of "long-term infrastructure" because they are building-agnostic and address campus-wide improvements. If one subtracts the estimates for new buildings ($1.7 billion) and off-site campuses ($209 million) from the total of $3.082 billion, the remaining balance ($1.2 billion) approximates the BMAR values ($1.3 billion) discussed above—an equivalence that further validates the need for this level of investment to sustain these facilities.

---

[12] Stephanie Hixson, NIH Office of Research Facilities, communication to Martin Offutt, National Academies of Sciences, Engineering, and Medicine, February 15, 2019.

[13] NIH Office of Research Facilities, "400 Project Dashboard," via e-mail, August 24, 2018.

TABLE 4.8 Project Dashboard (Excerpt)

Line	Description	Estimate ($000,000)	Attributable to Long-Term Infrastructure
2-85	Architectural, roof, elevator	115	
86-126	Central utility plant	162	162
127-171	Electrical distribution systems	310	310
173-183	Environmental/demolition	15	15
184-203, 344	Fire protection	59	
204-225	Garage roads and horizontal infrastructure	111	110
226-234	New buildings	1,730	
235-280	Institute-specific enhancements	124	
172, 281-284	Misc./emergencies/consultancies	40	40
285-343	Mechanical/comfort systems	157	
345-408	Off-site campus facility needs	209	
409-421	Security	29	29
422-436	Site needs	24	24
	Total	3,085	690

As noted, a number of these categories are campus infrastructure and essentially building-agnostic. These categories comprise systems (labeled above as long-term infrastructure) that are needed both to sustain the existing facilities and to support any future campus facilities. Should these systems not get the attention that they need, then the current facilities will not be supported regardless of their individual condition. The committee believes that these systems and the approximately $700 million in repairs and improvements associated with them in Table 4.8 must be addressed. The remaining $600 million in BMAR represents specific systems in specific buildings. The committee believes these also need to be addressed but should be considered in light of the comprehensive Master Plan and its approval. As each building's future designation is determined, the associated BMAR should be funded to support that designation. For example, the Combined Utility Plant on the Bethesda Campus has completed many upgrade projects in recent years to make the plant more efficient and sustainable. These upgrades generated cost savings and have increased the reliability of generation systems. In 2013, a dedicated "Utility Distribution Branch" was created to focus explicitly on the utility distribution systems. Recent upgrades include major power, steam, and condensate distribution lines and new walkable utility distribution tunnels. In addition, this branch has instituted Geographic Information System tracking of utility assets and nondestructive testing (such as infrared or ultrasonic testing) to detect leaks.[14] Based on the age and condition of those distribution systems, the committee believes it is imperative that NIH continue to focus funding on those projects to realize the efficiencies and reliability of the Central Utility Plant.

Many of these estimates have been included in previous Master Plan projects but on a piecemeal basis to support the individual needs of each requested facility. This scattershot method of separate requests leads to inefficiency in planning, procurement, and implementation. For example, decoupling the funding and ability to implement the infrastructure projects as a systematic restoration/upgrade program from individual Master Plan projects can improve current levels of service and sustainability, while simplifying the planning and implementation of system upgrades. These infrastructure projects can be implemented faster than the more complicated development of individual laboratory and support structures because they can be designed and procured in advance of specific building projects. By procuring these systems independently,

[14] NIH, "Central Utility Plant Distribution System: Past-Present-Future," presentation to the committee, March 20, 2018.

a more appropriate procurement can be developed to utilize utility contractors rather than facility specialist contractors.

FINDINGS AND RECOMMENDATIONS

Finding: The physical deterioration of the NIH Bethesda Campus facilities has outpaced the available resources and needs significant investment.

Finding: The "400 Project Dashboard" substantiates the calculation of the BMAR at approximately $1.3 billion. The committee believes these needs to be real and necessary to sustain current infrastructure and facility use. Approximately $700 million worth of projects are campus infrastructure and essentially building-agnostic. These categories comprise systems needed both to sustain the existing facilities and to support any future campus facilities.

Finding: The funding made available for facilities in the last 20 years (Figure 4.1) indicates that the repair and maintenance of the facilities competes with other facility needs each year, as can be seen by the variation in the amount of such funds devoted to construction. Without sufficient dedicated resources for repair and maintenance, the backlog of such needs will continue to grow.

Finding: The "400 Project Dashboard" indicates many specific needs organized by building or utility system. However, it is not organized in such a way as to prevent or minimize facility disruption or safety violations, or disruption of ongoing research—all of which impact mission dependency. Adoption of such a framework could support the prioritization of funds for maintenance and repair in light of other competitive facility needs.

Recommendation 4.1: The currently identified $1.3 billion in the Backlog of Maintenance and Repair (BMAR) should be funded in two tranches. First, fund the entire long-term infrastructure improvements totaling approximately $700 million over a specific time period (e.g., 5 years) so that a comprehensive plan can be undertaken to support the ongoing research activities and begin preparation and support for any future Master Plan improvements. (The full title is "2013 Comprehensive Master Plan—Bethesda Campus.") Second, the remaining $600 million needs to be considered for each building in light of its future as defined in the approved Master Plan.

Recommendation 4.2: The Buildings and Facilities account, or other account, should have an annual dedicated investment amount—determined by considering the amount of Backlog of Maintenance and Repair (BMAR), building condition index, and historical levels of spending—for reduction or elimination of BMAR that can be used only for this purpose.

Recommendation 4.3: NIH should adopt and implement a Deferred Maintenance and Repair program focused on building and utility system condition data that will minimize or eliminate specific failures that are disruptive to mission accomplishment and to reduce Backlog of Maintenance and Repair while attaining the building Condition Index (CI) target stated in the Master Plan. The methods that the committee recommends for capital planning prioritization—that is, incorporating CI and mission dependency—can be adapted for this purpose.

5

Current Capital Asset Management at NIH

DETERMINING THE VALUE OF FACILITIES ON THE BETHESDA CAMPUS

As noted in Chapter 3, the National Institutes of Health (NIH) Intramural Research Program (IRP) annually performs over $3.7 billion in research, primarily at the Bethesda Campus, and employs over 3,600 research professionals and some 5,400 non-full-time-equivalent trainees. The campus's facilities that house these research activities and personnel make it possible for NIH to accomplish its mission. Assessment of the value of these facilities in accomplishing the mission is essential for prioritization of investments in facilities.

Value of Real Property Assets

NIH real property falls under Executive Order 13327 (2004), which established the requirements for federal real property asset management, including a full inventory of real property assets, market valuation of those assets, and prioritized plans to improve the operational and financial management of those assets.[1] The U.S. General Services Administration (GSA) administers the Federal Real Property Inventory Reporting, and recently updated the calculations of Replacement Value as follows (FPRC, 2018, p. 22):

> Replacement Value is defined as the cost required to design, acquire and construct an asset to replace an existing asset of the same functionality, size, and in the same location using current costs, building codes, and standards. Neither the current condition of the asset nor the future need for the asset is a factor in the replacement value estimate.
>
> - Numeric values reported for replacement value must be greater than zero.
> - Failure to follow this guidance will result in inaccurate information on the FRPP condition index (CI), since CI is estimated based on replacement value.

[1] Executive Order 13327 of February 4, 2004, Federal Real Property Asset Management, *Federal Register* 69(25):5897-5900.

- Replacement value must be reported for all owned and otherwise managed buildings and structures regardless of facility condition, type, or whether it has been identified for disposal. For otherwise managed property, the "unit" should be based on the size (square feet of space) as specified in the agreement. Replacement Value for building assets must be a numeric value greater than or equal to the asset's square feet.

While the GSA recommends annually increasing the Replacement Value to reflect inflation, the functional replacement value (FRV) might more effectively reflect the value of the asset with respect to rapidly advancing research and development requirements. For example, the Current Replacement Value (CRV) of an existing surgical facility with limited floor-to-floor heights can be calculated from standard cost databases, but if the needs of the research program require additional floor-to-floor height plus more densely serviced communications and power lines to accommodate robotic assisted surgery research, the FRV may be tailored to more clearly reflect those additional costs. While it is the CRV that is widely used in calculating CI—indicating as it does the present condition of an asset—using the FRV for such purposes can offer an interesting comparison. A 2015 U.S. Government Accountability Office report notes that "GSA defines functional replacement value (FRV) as follows: FRV = Cost to replace the building's function (office, warehouse, etc.) and not the cost to replace the building as an exact replica of itself" (GAO, 2015, p. 5).

As noted in the 2012 National Research Council (NRC) report *Predicting the Outcomes of Investments in Maintenance and Repair of Federal Facilities*, "the primary objective of portfolio-based facilities management is to ensure that facilities-related investments enable the organization's mission" (p. 61). The report details several approaches that assess the value of facilities with respect to the risk of failure and the threat to achieving mission. For example, the Mission Dependency Index (MDI) assesses the damage from interruption or downtime from facility failure, which is used to prioritize investments. The U.S. Army Corps of Engineers developed the IMPACT simulation model to assess the impacts of delaying repairs on the service life of the equipment and consequent emergency repair cost (p. 64). The NRC report states:

> Facilities program managers should understand and be able to communicate effectively the economic value of a component or system to a mission, and the cost of protecting its value. To do that, they will need to identify the types of deterioration or other adverse events that will lead to loss of mission, the vulnerabilities of facilities to adverse events, the potential loss of economic value if a failure occurs, the accumulation of potential losses until the system is repaired, and how vulnerabilities can cascade into additional failures. (p. 77)

Another agency that utilizes the MDI is NASA. NASA adopted the MDI in 2004 with the goal to better manage facilities' risks and provide a better guide for investment and divesture decisions.[2] This approach involves asking the user to honestly assess the capability of the organization to perform its mission when the asset is not available. This allows decisions about repair, replacement, or disposal of capital assets to include the key discussion about impacts on mission accomplishment due to potential adverse events. It should be noted that there are times when the duration of the interruption is very short or other locations are available to facilitate relocation with little impact to the mission. But when that is not the case, it may be very appropriate to direct capital assets into existing or new facilities to ensure mission accomplishment (NASA, 2010). This is further discussed in the section "Using CI for Decision Making," below.

If the NIH capital asset management followed this approach, it could establish the value of the full functionality of its facilities in three ways:

1. Assess the relevant IRP budget affected by facility downtime (such as from power failures) or loss of productivity (such as from water damage) related to emergency repairs;

---

[2] NASA Facilities and Real Estate Division, "Notes on Using the Mission Dependency Index," https://www.nasa.gov/offices/FRED/directives_and_requirements.

2. Assess the potential value of the outcomes from the IRP research that are delayed, constrained, or cancelled due to facility downtime or emergency repairs; and
3. Assess the impact on patient care (such as travel time and wait time, delays in receiving treatment, and rescheduling) due to facility downtime or emergency repairs.

A recent report by the Institute for Defense Analyses (Howieson et al., 2013) cites four examples of federal security labs (i.e., those labs that conduct national security research and development) for which the management explicitly calculates the cost of facility disruptions in its prioritization of capital asset investments relative to agency mission:

- MIT-LL [MIT Lincoln Laboratory] developed the disruption index to indicate the degree to which a new project or alternatives to the project would interrupt current operations and research programs.
- NRL [Naval Research Laboratory] evaluates the disruption to ongoing research program as another consideration when prioritizing facilities, equipment, and F&I [facilities and infrastructure] projects.
- JHU-APL [Johns Hopkins University Applied Physics Laboratory] measures impact to its mission as the risk associated with the continuity of its customers' research programs.
- The Army's MEDCOM established the Facility Experience Index to consider aesthetics when evaluating F&I projects. The aesthetics index is based on a questionnaire completed by facility managers and patients that are weighted 75 and 25 percent, respectively. Although the aesthetics index is applicable only to medical treatment facilities (as relevant to the public's perception of the quality of their care), it provides an example of how MEDCOM is applying various concepts, methods, and tools to assess its F&I needs. (pp. 38-39)

PROCESS BY WHICH PROJECTS ARE PLANNED AND EVALUATED

Description of Process

NIH staff presented the organization, structure, and general process of the Facilities Working Group (FWG) and its subcommittees to the National Academies of Sciences, Engineering, and Medicine committee:[3] "The FWG is responsible for evaluating NIH's programmatic needs; balancing competing priorities; exploring alternative means of meeting NIH's changing needs for capital facilities; and reconciling them into a rolling 5-year Strategic Facilities Plan [i.e., the B&F/NEF-Funded 5-Year Plan], an annual Buildings and Facilities (B&F) Plan, and an annual Leased Facilities Plan."[4] Membership in the FWG consists of 11 voting members and 1 nonvoting member. The group includes representation of IC directors, IC scientific directors, and executive officers from various ICs appointed by the Director of NIH for 3-year terms.[5] Two subcommittees operate under the FWG, the Space Recommendation Board (SRB) and the Budget Committee. Under the SRB is a Research Facilities Advisory Committee (RFAC). The FWG advises the NIH Director and NIH Steering Committee on the planning, acquisition, development, and use of land and facilities. The NIH Steering Committee was formed to provide advice and recommendations on trans-NIH governance issues. This committee is chaired by the NIH Director, who appoints IC directors as members.[6]

The project list scored in the spring of 2018 indicates that all projects are the results of recommendations made by the Building and Space Plan Process. The spreadsheet, "B&F Project Prioritization Model for FY

[3] D. Wheeland, P.E., Director, Office of Research Facilities, "Open Discussion with FWG and RFAC," presentation to the committee, March 20, 2018.

[4] NIH Office of Intramural Research, "Facilities Working Group," https://oir.nih.gov/sourcebook/committees-advisory-ddir/facilities-working-group, accessed March 8, 2019.

[5] Ibid.

[6] NIH Office of the Chief Information Officer, "NIH Governance Groups," reviewed December 20, 2017, https://ocio.nih.gov/ITGovPolicy/Pages/NIH-Governance-Groups.aspx.

TABLE 5.1 Point Distribution in the Buildings and Facilities Project Prioritization Model for Fiscal Year 2019-2023 (Total Score of 1,000)

Criteria	Subcriteria	Points
Program impact	Mission criticality and/or intramural program affected for IC project	260
Project impact	Number of customers affected	40
	Building use	15
	Returns lease space to government owned	20
Functional obsolescence	Building function to support current, approved program	330
Facility evaluation	Building Condition Index	15
	Regulatory impact	45
	Building systems risk of failure impacting life safety and critical mission functions	222
	Sustainability	30
	Operating cost impact	23
Total		1,000

SOURCE: Dan Cushing, NIH Office of Research Facilities, "Projects Selection and Execution 2018 B&F Proposed Line Item Projects for Prioritization," presentation to the committee, May 15, 2018.

2019-2023 (Total Score of 1,000)," provided by NIH—hereafter "B&F Prioritization Model"—contains the components and potential point distribution list in Table 5.1. The 1,000-point scoring mechanism for each project/proposal shown in Table 5.1 has the following components: 335 points focused on IC Program Impacts; 330 points focused on Functional Obsolescence; and 335 points focused on Facility Impacts.[7] Simply stated, an evaluation with a high score means a potential adverse impact to the program and a greater risk of failure to building system/components including life safety and critical mission functions. Thus, a high score should lead to a high priority for the project to move forward.

The RFAC, the scientific director for remote campuses, and three executive officers review and score the Program Impact section. The Office of Research Facilities (ORF) B&F board reviews and scores the Facility Impacts section. The Functional Obsolescence section is scored by both groups.

Each of the subcriteria showing points in Table 5.1 has value guidance that is used by the scoring committee to select the potential portion of the available points for the subcriteria to apply to each project. As an example, the Facility Evaluation—Regulatory Impact (45 points) has four values:

- Must be addressed within 2 years 45 points
- Should be addressed within 3-5 years 30 points
- Can be addressed in conjunction with new project 7 points
- No regulatory impact 0 points

The specific regulatory issues and the magnitude of the issue, which might be expressed as the cost to correct, are not part of the evaluation. The only subcriterion that uses data is the building CI that results from the condition assessment process.

However, the B&F Prioritization Model does not weigh the key outcome of improved building CI with much importance. The maximum number of points for improving the building CI is 15 out of the 1,000-point total available for a project. Therefore, the condition index improvement, which translates to a reduction in Backlog of Maintenance and Repair (BMAR), represents only 1.5 percent of the total possible project score. The criteria for the 15 points available for the building CI are as follows:

[7] D. Cushing, NIH Office Research Facilities, "Project Selection and Execution," presentation to the committee, May 15, 2018.

- CI below 65 or project will increase CI to >90 — 15 points
- CI between 65 and 85 or Central Utility Plant — 8 points
- CI over 85 or new construction — 0 points

The U.S. Department of Agriculture (USDA) by contrast uses a degree of portfolio-level analysis of the BMAR to focus the capital investment strategy. *The USDA Agricultural Research Service, Capital Investment Strategy*, *April 2012* (USDA, 2012) provides the ranking of each facility from worst to best based on the CI. All facilities are assigned a priority of 1 to 4 based on the importance of the research programs to the mission. These priorities are systematically evaluated by senior research program leaders. USDA then reviews, portfolio-wide, the combination of the facility's CI rank with the highest priority research. This analysis drives the decisions on where the capital investment recommendations will focus, considering economic restraints.

NIH Bethesda Campus projects are categorized into three sections (A, B, or C). Section A projects have a complete program, environmental impacts, and cost estimate and are included in the Master Plan. Section B projects are those with incomplete documentation that would otherwise have been required for the projects' inclusion in Section A. Those in Section C are minimally defined projects. Projects are considered for B&F funding if they have a high score and are in Section A. The timing of when projects progress through the planning and construction process is based on the availability of funds and the completion schedule of other projects.

One example with a low CI, placed in Section B due to an incomplete priority scoring index, is the replacement of Building 12. Building 12, which houses the data center, is slated for replacement in the Master Plan and currently has not been funded while awaiting completion of fiscal year (FY) 2018-2022 Priorities. The CI for the existing building is 51.7, which is extremely low for the campus, and the B&F Priority score for Functional Obsolescence section is currently 165 out of 330 possible points. This score is far less than one would expect for a building with such a low CI and that provides research services that are available to all ICs. Further, the building is at risk due to inadequate utility capacity, including an estimate showing inadequate generator power capacity by 2020, and chilled water-cooling capacity in 2017. A project to increase chilled water capacity has received funding and begun construction. From 2015 to 2017, the high-performance computing (HPC) system, Biowulf,[8] has seen a net increase of users for HPC of 78 percent, principal investigators of 53 percent, CPU hours of 345 percent, and storage used of 100 percent. (Biowulf is discussed further in Chapter 3, in the section "Data Science Infrastructure and High-Performance Computing.") It is surprising that a building with this kind of growing impact on research has not moved forward quickly with appropriate analysis into Section A due to its low CI score and potential infrastructure failures.[9]

Condition Index Assessment

The condition assessment contractor's process is to initially gather aggregated system-level information to determine deferred maintenance and capital renewal. The primary focus is to determine the age of each system, compare the age to the industry standard life expectancy for each system and project estimated remaining life based on the comparison (age versus life expectancy), making adjustments to estimated remaining life based on visual condition observations or maintenance histories. This develops a data source that can be updated as systems age and building conditions change. The process includes an update by the contractor on a 4-year cycle based on field observations and updated condition information. System

---

[8] A. Baxevanis, "BIOWULF High Performance Computing at NIH," presentation to the committee, May 16, 2018.

[9] NIH Center for Information Technology, "High-Performance Computing Services," https://www.cit.nih.gov/service/high-performance-computing-services.

replacement costs are based on the industry cost estimating source RSMeans.[10] The replacement cost of the systems is based on the current capacities and characteristics (in-kind). The costs are adjusted for factors such as geographic location (factors provided by RSMeans) and any factors NIH uses for construction on campus. Each year the BMAR and CI are recalculated based on the updates described above and inflation. The BMAR data provided by NIH includes a report that shows the projected increase in BMAR per year per building.[11] The current year BMAR is used to calculate the current year CI, which is used in the project scoring process described above.

The BMAR that results from the assessment approach is used in a limited fashion to develop a small segment of the project scoring process. Approximately two-thirds of the annual B&F appropriation is used for smaller projects in the category of Repairs and Improvements. These projects are developed by the NIH facilities staff with knowledge of the day-to-day operations, as discussed in Chapter 4, in the section "Project Dashboard." There is not a direct link to the BMAR in the development of these projects.

PLANNING ENVIRONMENT

Long-Range Planning Process

The long-range planning process at NIH is overseen by the NIH Director and driven by the aforementioned FWG and its subcommittees.

The Bethesda Campus Master Plan was issued in 2013 and completed the associated National Environmental Policy Act Record of Decision in 2015. This plan had input from the NIH Director and the FWG and provides guidance to the long-range planning process. It encompasses a number of the Director's strategic themes for future improvements.[12]

The rolling 5-year B&F/NEF-Funded Plan described in the previous section includes projects that have been selected via the B&F Prioritization Model. Projects are "generally considered for funding if they score over 500 points" and have complete program, environmental and cost data.[13] However, it appears that this threshold is not always used. For example, the FWG has placed a project (Building 40 Lab Addition) on the Projected Timelines with Funding even though it has a score of 250, which is well below the 500-point threshold for funding. This indicates that unrecorded factors must have been considered.

Project timing is dependent on availability of funds and when predecessor projects are complete (if applicable). This plan is reviewed and approved by the FWG.[14] Projects seem to originate from those identified in the Master Plan, the Director's thematic focus areas, functionally underperforming facilities (i.e., low-CI facilities), grass roots (as in the case of Biowulf high-performance computing and its associated facilities' needs), or programmatically based on specific targets (e.g., the Porter Neuroscience Research Center project). In a more prospective vein, the IRP in June 2015 issued an implementation plan (NIH ACD, 2015) responding to the Advisory Committee to the Director report to the NIH Director on Long-Term Intramural Research Program Planning (NIH ACD, 2014). Both the implementation plan and the report look forward in terms of new areas of investigation and can inform the long-range facilities planning process.[15]

---

[10] RSMeans "provides accurate and up-to-date cost information that helps owners, architects, engineers, contractors and others to precisely project and control the cost of both new building construction and renovation projects." See http://www.rsmeans.com.

[11] NIH Office of Research Facilities, "Running BMAR Tallies by Year and Building," sent via e-mail, February 22, 2018.

[12] D. Wheeland, NIH, "NIH Bethesda Master Plan," presentation to the committee, March 20, 2018.

[13] D. Wheeland, NIH, "Buildings and Facilities Scoring 2017," presentation to NIH Facilities Working Group, June 14, 2017.

[14] D. Cushing, NIH Office of Research Facilities, "Annual Budgets: Buildings and Facilities, Facilities Maintenance, and Process," presentation to the committee, March 20, 2018.

[15] M. Gottesman, M.D., "Facilities vis-à-vis Scientific Mission," presentation to the committee, May 15, 2018.

As noted in the previous section, the B&F Prioritization Model sorts proposed projects into three tiers. Projects on the B&F Section A list can be funded using the baseline B&F funding, nonrecurring expense funds provided by the Department of Health and Human Services (HHS), specific emergency allocations (such as Biodefence [2003] and the American Recovery and Reinvestment Act [ARRA, 2009] from Congress)[16] or one-time increases for major individual capital projects as line items approved by Congress (such as Building 50). Projects also can be funded using IC appropriated funds subject to a $3.5 million cap on individual projects and $45 million NIH-wide cap per year—the so-called special authority discussed in Chapter 4. Facilities' nonemergency maintenance projects over $75,000 are handled by ORF using B&F funding. The B&F/NEF-Funded 5-Year Plan is reviewed annually by HHS. Project proposals that are considered for approval must have a Facility Project Approval Agreement.

There is no external (i.e., outside NIH or federal government) input into the long-range planning process. All the committees consist of senior employees of the ICs and Office of the Director. It is unclear if there is input from NIH personnel at more junior levels into the process.

Constraints and Challenges

As with most organizations, capital planning for the long range at NIH faces a number of challenges and constraints, some of which are unique to the Bethesda Campus:

- B&F funds have been essentially static for the past 20 years (around $128 million per annum), with a 5-year expiration (not *X*-year, or nonexpiring); this level of funding has not allowed the organization to keep up with inflation or to pool funding for larger capital expenditures. The B&F appropriation increased to $200 million for FY 2019.
- Over the past two decades, the funding stream has been sporadic for large capital expenditures from either special authority or through one-time appropriations (e.g., ARRA in 2009) or when certain projects are picked up by Congress (Biodefense in 2003).[17] This sporadic funding stream does not allow a smooth and logical progression of projects. In some cases, the planning for a facility becomes obsolete before it is funded, leading to inefficiency. This also tends to lower morale among those who are performing the planning.
- The campus has a large backlog of deferred maintenance items, which at times lead to emergencies at specific facilities, and a continued growth in operation and maintenance costs at those facilities. It does not appear that the maintenance backlog is addressed in a systematic manner or is tied to the long-range plan. In other words, if the long-range plan is to demolish and replace an existing facility, one can question how decisions are made regarding further significant investment in that facility. Nor does it appear that ORF has sufficient flexibility in how it utilizes the B&F account to implement a program of preventative maintenance such as might decelerate the growth in BMAR.[18] When the funding window for a project continues to be pushed back, the facility continues to degrade. An example of this is the Building 14/28 complex (vivarium), which may impact the ability to continue its accreditation, while operations and maintenance costs escalate. For example, in the past 5 years NIH has spent in excess of $19 million for renovations on this complex.[19] (See Recommendation 4.3.)

---

[16] D. Cushing, NIH Office of Research Facilities, "Annual Budgets: Buildings and Facilities Maintenance and Process," March 20, 2018.

[17] Ibid.

[18] Studies of test portfolios of F&I show a positive net-present value for preventative maintenance. See, for example, Jones Lang Lasalle, "Determining the Economic Value of Preventive Maintenance," https://gridium.com/wp-content/uploads/economic-value-of-preventative-maintenance.pdf, accessed July 24, 2019.

[19] NIH Office or Research Facilities, "20180927 Bldg 14 28 and 12 obligations last five years" via e-mail September 27, 2018.

- The rapidly changing technological innovations and opportunities in medical research that NIH should pursue as part of its mission makes its ability to perform long-range planning more difficult. The solution to this dilemma is to build modularization and flexibility into all facilities looking at long-range needs, perhaps with the idea of turning over a majority of each new facility every 5 to 10 years to new requirements.
- The diverse mission requirements of 27 IC are a challenge when trying to balance the requirements of NIH, and the needs of the individual IC. The challenge of addressing agreements on expenditures is solvable, but requires a tremendous amount of communication, education (e.g., expenditures on shared core utilities), and input back into long-range plans. The long-range plan must be aligned to the strategic direction of NIH collectively and vice versa, taking a proactive approach.
- As discussed in Chapter 4, funds appropriated to the ICs, up to $3,500,000 per project, can be used to cover costs associated with altering, repairing, or improving NIH facilities. The funding ceiling for all ICs collectively cannot exceed $45,000,000. Historically, an average of roughly $35,000,000 has been spent on these types of projects.[20] This number is admirable; however, it does leave some funding unspent, requires significant coordination to provide the funds for projects (as the moneys are held by the ICs and have to be released by them, which may generate a conflict of objectives), and reduces the amount of research that ultimately can be accomplished.

ASSESSING THE NEED FOR RENOVATION, REPLACEMENT, OR ADAPTIVE REUSE

The Utility of the NIH Condition Assessment and B&F Prioritization Model

The Government Accountability Office identified the following leading practices to manage deferred maintenance and repair backlogs:[21]

1. Establish clear maintenance and repair objectives and set priorities among outcomes to be achieved.
2. Identify assets that are mission-critical and mission-supportive.
3. Conduct condition assessments as a basis for establishing appropriate levels of funding to reduce any deferred maintenance and repair backlog.
4. Establish performance goals, outcome baselines, and performance measures.
5. Identify the primary methods to be used for delivering maintenance and repair activities.
6. Employ models for predicting the outcome of investments, analyzing trade-offs, and optimizing among competing investments.
7. Align real property portfolios with mission needs; dispose of unneeded assets.
8. Identify the types of risks posed by lack of timely investment.
9. Structure budgets to identify funding allotted (1) for maintenance and repair and (2) to address any backlog of deferred deficiencies.

While NIH has a condition assessment process, not all of the leading practices are followed. As it relates to the capital investment strategy, it is not clear that NIH establishes performance goals, outcome baselines, and performance measures associated with projects. NIH does not predict the outcome of the investment and measure the success. A sampling of project documents did not show current operating costs and the anticipated new operating costs by square foot to set a benchmark to measure the success of the project in

[20] D. Cushing, NIH Office of Research Facilities, "Annual Budgets: Buildings and Facilities Maintenance and Process," presentation to the committee, March 20, 2018.

[21] M. Armes, U.S. Government Accountability Office, "Federal Real Property Management Issues," presentation to the committee, March 21, 2018.

reducing those costs after project completion. Based on the information provided, NIH's use of the condition assessment information is very limited. The assessment data are used to develop the CI to assist in the score of a project and along with the BMAR provide information that supports reporting needs across the portfolio. However, the actual use of the assessment data in the planning process was not demonstrated.

The condition assessment provides little impact on the project scoring process as described and weighted. Improving the building condition index is described in the Master Plan as one of the key outcomes. However, the criteria for selecting a value uses only the change in CI, which shows that the results of the condition assessment has little to no utility in identifying facilities with the most need. As noted above, the committee received a presentation of the condition assessment data and CIs showing that Building 12 was in very poor condition (CI of 51.71) and recommended for demolition by the Master Plan Subcommittee[22] as part of a larger scheme in that area of the campus to bring leased lab space onboard and to replace and modernize waste transfer and storage facilities (NIH ORF, 2013, pp. 5-20 and 5-24). Building 12 has recently had a significant investment, including one of $37 million for an uninterruptable power system (situated outside the building and thus movable), $5 million for increased cooling capacity, and $2.4 million for miscellaneous improvements.[23] (This is in addition to investment in the information technology that resides in Building 12, part of NIH's move into high-performance computing.)[24] Despite what the BMAR and CI might imply about a building's viability, the needs of the research program—for high-performance computing in this case—indicates that NIH is making significant investments in buildings recommended for demolition by the Master Plan.

The CI is a relative indicator of the condition of a facility when compared to similar facilities. The CI by itself does not discern between the criticality of the deferred maintenance or the system that is impacted in the facility. Therefore, one facility could have a CI that identifies that it is in worse condition than another. However, the facility with a better CI may have deferred maintenance concentrated in critical systems (e.g., HVAC, electrical, plumbing, roof) and thus represent greater risk. The NIH has not provided any portfolio-wide analysis showing a more in-depth look at the data and how it could inform their processes and plans.

As discussed in Chapter 4, in the section "Risk to Research and Patient Care Created by Outages and Disruptions," NIH performed an analysis of risk associated with the Building 10 complex for some critical systems (i.e., mechanical, electrical, and distribution) and for the function and amount of space.[25] This appears to be a specific example of using the condition information for the Building 10 complex to analyze risk. A formalized risk assessment using this approach could be extended to other facilities in the portfolio.

CI is calculated based on current year deferred maintenance and current replacement value. However, the planning process is at best a 5-year timeline. The condition assessment contractor hired by NIH provides reports that project the BMAR changes by year for the next 10 years. Therefore, the annual change in CI can also be projected. The committee believes that the current and projected CI could be used in the project scoring process to account for the length of time associated with the planning and funding process and any potential significant changes in BMAR during that period. This process would further define and prioritize the projects to which the $600 million suggested in Recommendation 4.1 would be applied.

The condition assessment process addresses the projected replacement of systems based on age and adjusted according to condition observations. The condition assessment process generates the BMAR and CI. The CI (15 points—1.5 percent) is the only data driven factor in the Facility Evaluation criteria in the B&F Prioritization Model (see Table 5.1). Other facility issues such as accessibility, environmental concerns, code compliance, operating cost savings (e.g., energy savings), and sustainability are not quantified by other specialized inspection services or studies. The B&F Prioritization Model uses the

---

[22] D. Wheeland, NIH, "Bethesda Campus Master Plan," presentation to the committee, March 21, 2018. Also see NIH ORF (2013), p. 5-29.

[23] NIH, "1-10-19 Questions and Answers with Table," via e-mail, January 11, 2019.

[24] Stephanie Hixson, NIH, "Bioinformatics and High-Performance Computing," presentation to the committee, May 16, 2018.

[25] D. Cushing, NIH Office of Research Facilities, "Capital Projects on Deck, Shovel Ready & Emerging," presentation to the committee, March 20, 2018.

subjectivity of the committee to score regulatory impact, sustainability, and operating cost impact rather than quantifiable measures that could drive the process such as the change in square foot operation costs potentially achieved by the project.

The functional obsolescence values in the scoring process subjectively rate how building systems support current program(s) located in the building. The analysis of functional obsolescence could be included in the condition assessment process to identify and quantify the requirements.

Committee's Assessment

The NIH has developed many large construction and renovation projects based on the Master Plan and there are several system replacement projects on the funded project list, including the fire alarm reliability for the Clinical Center (CC) and emergency power to assure chilled water, which are more limited in scope. The funded projects and the projects in the planning phase are all needed. However, the committee was not able to discern that a specified standard process is used to determine which projects address the most important needs of the campus.

Throughout the committee's interactions with NIH staff and in the various presentations to the committee, a number of recurring themes were voiced. These included the poor condition of the animal facilities, the lack of infrastructure to support data analytics and computing needs, constraints in the clinical facilities, the challenges of managing campus infrastructure projects, and the goal of reaching a CI for all facilities at the Bethesda Campus of 90 or above. Site visits to facilities by committee members confirmed the challenges facing NIH in these regards and their mission criticality. Chapter 3 of this report provides a description of the animal facilities, data infrastructure, and CC. Some examples of the challenges they face are provided below.

The animal facilities housed in Buildings 14B to 14H and 24 are contiguous, and due to their age and deteriorated condition could become a licensing problem absent appropriate intervention. These buildings house animals that are not located within a laboratory building and have a significant impact on the success of research across many institutes. The Division of Veterinary Resources manages most of these buildings. The average CI for these buildings is 78, and all but one is over 60 years old. Replacement of this complex of buildings will provide the opportunity to rightsize capacities, provide a modern mechanical-electrical-plumbing system, allow for redundancy in mechanical and electrical systems, and increase reliability and reduction in maintenance and energy costs. These facilities continue to experience critical failures in building performance—for example, during the weeks of December 28, 2017, to January 10, 2018, failures included seven days of HVAC failure in Building 14D, low/high temperature failures, and floods in surgery.[26] The lack of essential mechanical infrastructure upgrades prevents the program from meeting basic NIH needs for the largest animal holding facility on campus. The long-term plans include replacement of the facility as part of the Center for Disease Research (CDR). The *2013 Comprehensive Master Plan—Bethesda Campus* envisaged the North Development of the CDR for the existing 7 and 9 building sites, although the NIH Office of Research Facilities advises that the location of the CDR is being reevaluated.

The pursuit of this project should include review of all options for housing animals. NIH needs not only to consider replacement of the current Building 14/28 complex but also to look at other options. These include the acquisition of facilities beyond the current campus that would have less impact on future programmatic growth for other key NIH programs and consideration of third-party solutions that include leasing of existing facilities or outsourcing animal facilities to a third party. These kinds of options are often considered by other biomedical research organizations, and it is not assumed that one option is more viable than another.

Another project impacting the mission of many if not all NIH institutes is the computer center (Building 12 complex). As discussed earlier in this chapter, utilization of the computer center is growing dramatically,

[26] S.M. Roberts, R.A., NIH, "Animal Facilities," presentation to the committee, March 20, 2018.

and the current building has reached its limits for infrastructure needs. The need for a new facility includes the following criteria:

- Co-location of experts in the computational, statistical, and data sciences;
- Replacement of obsolete infrastructure to empower mission-critical computational and data science; and
- Support of current and emerging science with high-performance/flexible building infrastructure.

Like the animal facility, this project should look at all alternatives as well, but is faced with obstacles that are unique to high-speed computing. A location off site may not be practical due to high-speed dedicated data lines located under public rights-of-way, which can be costly to install and maintain. A formidable challenge for NIH is ensuring security of the data and site, which may make a remote location impractical. Another possibility is to contract with a third party to build and manage a new computing facility on campus.

Building 10, which houses the CC, was originally constructed in 1953, with a number of additions in the interim—including the new Mark O. Hatfield Clinical Research Center constructed in 2005. Portions of the Building 10 complex assigned to the CC have experienced serious deferred maintenance failures impacting mission accomplishment. Parts of the facility, including the existing surgical center, are functionally obsolete. Its ability to handle an increasing load of outpatient activities is limited and problematic. As a result, a number of the projects in Section A of the B&F 5-year plan are focused on improving the CC capabilities and functionality. Over $8.3 million in funds appropriated to ICs—applying the special authority of up to $3,500,000 per project—were used to cover costs associated with altering, repairing, or improving CC facilities during the past 5 years.[27] As discussed in Chapter 4, in the section "Project Dashboard," NIH has a listing of over 400 repair and improvement projects for future funding.

In FY 2017, $212 million of BMAR was attributable to the CC.[28] Given that the CC is a "unique in the world facility" that provides strategic leverage for NIH and supports the ability of a large number of its ICs to accomplish their missions, failure of any CC capabilities is problematic to NIH.

The committee believes that NIH should continue its efforts to enhance campus infrastructure. Since the formation of a dedicated Utility Distribution Branch in 2013 to assess the current condition of the distribution system and respond to needed repairs and look long term for future projects (replacements), the campus has completed numerous commendable improvements. Examples of completed or underway projects include replacement of chillers in the Central Utility Plant, addition of emergency power generation for chilled water, electrical power reliability for the CC, a new chilled water storage facility (the Thermal Energy Storage system; Building 34 in Figure 4.2), and chilled water monitoring stations in the Central Plant for "real time" data on system performance. The committee believes efforts by this group should continue and be supported with sufficient funding to ensure improved systems reliability; however, these should be evaluated utilizing the Mission Dependency Index as discussed below.

Using CI for Decision Making

Comparable Methodologies

The contractor that NIH uses to perform the condition assessment and maintain the database of that information has several federal agency clients, as well as many research colleges and universities, hospital systems, and private research businesses. The process they use is very similar in nature to the primary approach that the Department of Defense (DoD) and the individual branches of the military use.

---

[27] NIH, "1-10-19 Questions and Answers with Table," via e-mail, January 11, 2019.

[28] NIH Office of Research Facilities, "The Clinical Center Complex: History of Architectural and Engineering Development," handout to the committee, March 20, 2018.

> The BUILDER™ Sustainment Management System (SMS) is a web-based software application developed by ERDC's [Engineering Research and Development Center's] Construction Engineering Laboratory (CERL) to help civil engineers, technicians and managers decide when, where and how to best maintain building infrastructure. Because building assets are so vast and diverse, a "knowledge-based" philosophy drives the BUILDER™ SMS process. The process starts with the automated download of real property data, and then a more detailed system inventory is modeled and/or collected which identifies components and their key life cycle attributes (e.g., the age and material). From this inventory, Condition Index (CI) measures for each component are predicted based on its expected stage in the life-cycle.[29]

Using Condition Assessment Data and CI in Decision Making

NIH has developed many large construction and renovation projects based on the Master Plan from 2013 (fully described in Appendix H) and the rolling 5-year B&F Plan[30] that is prepared annually and includes funded projects.[31] There are several system replacement projects on the funded project list, including the fire alarm reliability for the CC and emergency power to ensure chilled water, that are more limited in scope. The committee accepts that all the funded projects, as well as the projects in the planning phase, are needed; however, the committee was unable to discern that a recognized and standardized process was used to determine whether and to what degree these projects address the most important needs of the campus.

The strength of using CI metrics is in identifying the buildings in poor condition in a significant portfolio of facilities. The National Park Service recognized that there are limitations to the CI as the only indicator of condition in developing their Life Cycle Business Practices (NPS, 2006). The CI is simply a relative indictor of condition within a group of homogeneous facilities. The wide variety of facility types combined with the significant level of the deferred maintenance required a more focused use of the condition assessment data. NPS developed a critical systems approach, including priority criteria for each deficiency that are based on risk to the facility and safety (minor, serious, and critical). Additionally, NPS identified the critical systems for each asset type. Therefore, the serious and critical deficiencies within critical systems informs the development of projects.

The NPS condition assessment identifies work required for facilities to comply with legislatively mandated requirements of accessibility, fire/structural, life safety, and code compliance. The existence and the cost of correcting these issues are considered during project development and scoring.

As described above, in the section "Process by Which Projects Are Planned and Evaluated," there is an opportunity for NIH to utilize a Mission Dependency Index (MDI) to compare one building to another to prioritize their needed improvements based on "mission impact." Strategically, this is particularly important when choices must be made between individual buildings for limited B&F funding. The same methodology can be used in the CI analysis by recognizing that not all infrastructure systems that support a building are equal—some may have a more serious impact on successful operation of the building. The two methodologies' linkage is simple—CI considers the probability of infrastructure failure and MDI identifies the severity of the failure. This would be a way to prioritize the findings utilized in the Backlog of Maintenance and Repairs to allow a more strategic focus on system expenditures and repairs.

Likewise, the committee believes that efforts should be made to utilize the Mission Dependency Index concept to develop data across the Bethesda Campus portfolio to quantify the requirements to upgrade campus-wide facility and infrastructure systems to meet current and future programmatic needs. This then

---

[29] See https://www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/476728/builder-sustainment-management-system/.

[30] D. Cushing, NIH Office of Research Facilities, "Capital Projects: On Deck, Shovel Ready & Emerging," presentation to the committee, March 20, 2018.

[31] D. Cushing, NIH Office of Research Facilities, "Projects Selection and Execution 2018 B&F Proposed Line Item Projects for Prioritization," presentation to the committee, May 15, 2018.

can guide the Utility Distribution Branch team in their program (see the above section, "The Utility of the NIH Condition Assessment and the B&F Prioritization Model").

FINDINGS AND RECOMMENDATIONS

Finding: All federal agencies are required to maintain a facility Condition Index as part of their real property asset management. Federal agencies such as the U.S. Army Corps of Engineers, NASA, and the three federal security labs referenced in this chapter explicitly calculate the cost of facility disruptions in the prioritization of capital assets. NIH does not appear to do so currently.

Finding: NIH does not appear to have taken advantage of the capital asset management expertise existing in other federal agencies that manage large capital programs. NIH could utilize the expertise found in these agencies to improve its practices and procedures.

Finding: Building 12 housing the NIH computer center, the Building 14/28 Complex housing animals, and the Building 10 CC provide resources that are available to all institutes and centers, and any temporary loss of their functionality due to facility failures imposes a significant negative impact on operations and mission accomplishment. While the projects involving these facilities appear to be important, the committee believes that their priority should be confirmed by use of a model that is more objective-based.

Finding: While projects are generally considered for funding if they score over 500 points, there is an example of a project in Section A of the 5-Year NIH Buildings and Facilities Master Plan with a score of 250 points (Building 46A, Vaccine Research Center Addition). This leaves the impression that there are unrecorded subjective factors that came into play during the ranking process.

Recommendation 5.1: NIH should revise its Building and Facilities (B&F) prioritization model so that a significant portion of the 1,000-point scoring system (no less than one-third of the total points) includes the Condition Index and Mission Dependency Index as objective parameters. Using this revised model, NIH should reassess all current projects in the 5-year B&F plan. The balance of the $1.3 billion of funding (i.e., $600 million) should be prioritized based on this assessment. This assessment could also be used to determine the annual required funding set aside.

Recommendation 5.2: NIH should utilize the changes in the Building and Facilities prioritization model to complete an analysis of projects to modify or replace Building 12, the Building 14/28 complex, and various active or planned projects to renovate or replace portions of Building 10 occupied by the Clinical Center. If the analysis supports a high priority for these projects, then NIH should continue with efforts to move forward as quickly as possible with these projects.

Recommendation 5.3: NIH should seek out the federal agencies referenced in this report, along with other similar agencies, to determine if there are best practices that it can utilize. NIH should consider regular (e.g., quarterly) engagements with these agencies to review its Capital Asset Management Program, as well as how the engagement of key individuals from the institutes and centers (at all levels of the organization who are impacted by the program) and the private sector could enhance the success of NIH projects.

ANNEX 5.A: PREVENTATIVE MAINTENANCE MEASURES AND LIFE CYCLE COST ANALYSIS

Preventative Maintenance Measures

While NIH staff members spent little time on integration of maintenance activities into long-range planning during their presentations to the committee, it is worth mentioning that this may be an opportunity if NIH's current efforts are not rigorous in this regard. Integration of maintenance into long-range planning would allow better optimization of funding opportunities, and at the same time inform the planning process from a prioritization perspective.

Underscoring the importance of preventative maintenance, experts have judged that 2 to 6 percent of an annual operating budget should be allocated to preventative maintenance to minimize a facility's rate of degradation.[1] Preventive maintenance both saves money and forestalls the need to replace a facility—which might otherwise require capital and time owing to time needed for evaluation and design to funding and implementation. Preventive maintenance especially helps reduce building failure and poor conditions that can negatively impact mission critical building operations, energy efficiency and employee morale.

According to one analyst (Hemmerdinger, 2014, p. 4), "such a comprehensive operations and maintenance program for energy and water systems, based on proactive, predictive maintenance and analytics, can save up to 20 percent per year on maintenance and energy costs, while increasing the projected lifetime of the building by several years." The report, *Operations and Maintenance Best Practices: A Guide to Achieving Operational Efficiency* (FEMP, 2010, p. 5.4), Release 3.0, indicates that savings can be even greater for the best in class Predictive Maintenance programs:

- 10-times return on investment
- Reduction in maintenance costs: 25-35 percent
- Elimination of breakdowns: 70-75 percent
- Reduction in downtime: 35-45 percent
- Increase in production: 20-25 percent

Predictive maintenance can incur higher initial costs, for example, owing to funds needed for new software for capturing data on the condition of systems and equipment. It is further likely that additional staff or contractors would be required to make the needed repairs with attendant increase in maintenance costs. Ideally, the organization implementing predictive maintenance would have staff with the technical expertise to analyze the data coming out of the building management system and compare that information against optimal performance benchmarks. It is envisaged that using the predictive maintenance approach, repairs and improvements would be prioritized based on potential cost and mission impact. Supporters of this approach believe that predictive maintenance can extend the lifetime of a building by several years and deliver ancillary benefits such as "increased safety from properly maintained equipment, greater comfort and productivity for occupants, and better compliance with efficiency requirements" (Hemmerdinger, 2014, p. 7).

Designing for Minimum Life Cycle Costs

As with the topics of preventive maintenance measures and long-range planning, there was little discussion during presentations to the committee and follow-up question and answer sessions regarding life cycle cost analysis. This concept is integral to the Department of Defense (DoD) energy and nonenergy projects, as well as being outlined in guidelines by the Office of Management and Budget (OMB) Circular A-91.

[1] P.S. Kimmel, AIA, IFMA Fellow, 2009, IFMA Benchmarking Report.

Life Cycle Cost Analysis (LCCA) "is a method of evaluating the cost-effectiveness of project design decisions." LCCA

> Properly accounts for many project cost variables. These include a wide variety of project costs (e.g., construction, operations, maintenance, replacements, utilities, etc.) [Figure 5.A.1]. They also encompass the time value of money, including a project-specific discount rate, inflation, and cost escalations for a variety of goods and services. … Performing an LCCA study involves (1) establishing objectives for the analysis, (2) determining the criteria for evaluating alternatives, (3) identifying and developing design alternatives, (4) gathering cost information, and (5) developing a life cycle cost for each alternative. (Stanford University, 2005, p. 12)

As described in the Whole Building Design Guide (WBDG) series of documents,[2]

> LCCA can be applied to any capital investment decision in which relatively higher initial costs are traded for reduced future cost obligations. It is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance but may have different initial investment costs, different operating and maintenance and repair costs, and possibly different lives. LCCA provides a significantly better assessment of the long-term cost-effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run.

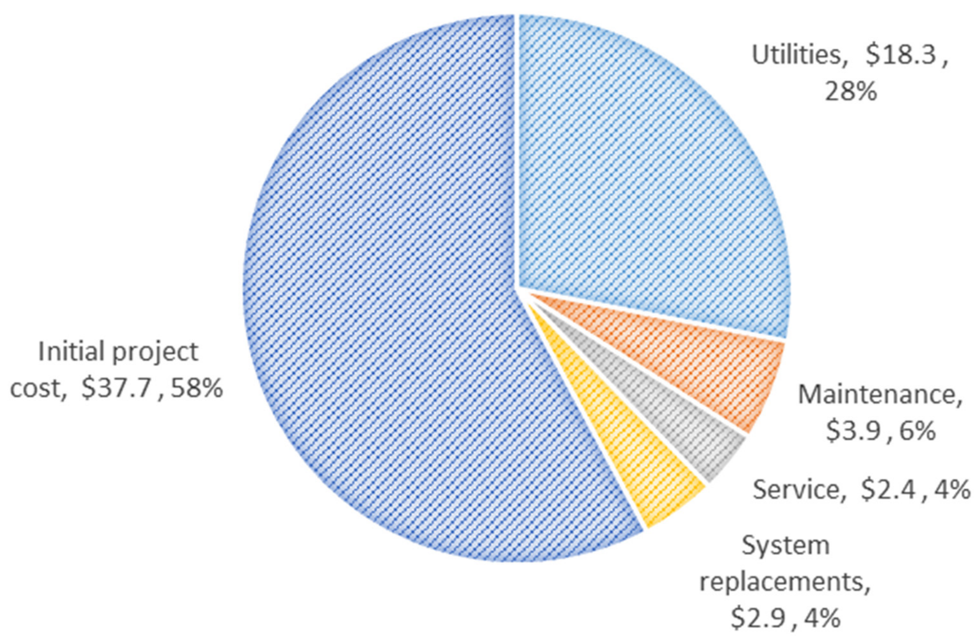


FIGURE 5.A.1 Illustrative breakdown of life cycle costs ($000,000). The data are from the Gates Computer Science Building at Stanford University. SOURCE: Adapted from Stanford University (2005).

[2] Sieglinde Fuller, NIST, September 19, 2016, "Life-Cycle Cost Analysis (LCCA)," http://www.wbdg.org/resources/life-cycle-cost-analysis-lcca, accessed March 8, 2019.

The WBDG further notes that[3]

> LCCA can be performed at various levels of complexity. Its scope might vary from a "back-of-the-envelope" study to a detailed analysis with thoroughly researched input data, supplementary measures of economic evaluation, complex uncertainty assessment, and extensive documentation. The extensiveness of the effort should be tailored to the needs of the project.

WBDG further notes that for OMB projects,[4]

> Office of Management and Budget (OMB) Circular A-94—Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, October 1992, applies to building-related benefit-cost or cost-effectiveness analyses of federal programs or policies that are not primarily concerned with energy or water conservation or renewable energy projects. Appendix C of Circular A-94, updated annually in February, provides the OMB discount rates.

LCCA, and likewise for Federal Energy Management Program (FEMP) projects[5]

> The Federal Energy Management Program (FEMP) has published life-cycle costing rules and procedures [Code of Federal Regulations, Title 10, Part 436, Subpart A]. These FEMP rules are consistent with OMB rules. They are to be followed by all federal agencies, unless specifically exempted, in evaluating the cost-effectiveness of potential energy and water conservation projects and renewable energy projects for federally owned and leased buildings. NIST Handbook 135, Life-Cycle Costing for the Federal Energy Management Program, explains and amplifies the LCC rules of FEMP. The Annual Supplement to Handbook 135, Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis [NIST, 2017b], updated annually on April 1, provides the FEMP discount rates. The same publication contains tables of discount factors for time periods up to 30 years, using either the OMB or FEMP discount rate. The FEMP discount factors also include the most recent energy price escalation rates projected by the Energy Information Administration (EIA). The discount factors are embedded in BLCC and other federal LCC computer programs.

For the DoD,[6]

> The Tri-Services Memorandum of Agreement (MOA) on "Criteria/Standards for Economic Analyses/Life-Cycle Costing for MILCON Design" provides the guidelines for LCCA for DoD energy and non-energy projects.[7] These guidelines are consistent with FEMP and OMB guidelines. However, the MOA recommends (but does not require) that cash flows are discounted from the middle of each year rather than from the end of each year as are cash flows of FEMP and OMB projects.

---

[3] Ibid.
[4] Ibid.
[5] Ibid.
[6] Ibid.
[7] U.S. Army Corps of Engineers, U.S. Air Force, and U.S. Navy Facilities Command, March 18, 1991, "Memorandum of Agreement on Criteria/Standards for Economic Analyses/Life-Cycle Costing for MILCON Design," https://www.wbdg.org/FFC/DOD/dod_moa_lcca.pdf.

6

NIH Current Approach to Strategic Planning for the Bethesda Campus Buildings and Facilities

This chapter describes the current National Institutes of Health (NIH) approach for strategic planning and capital project management, including the rationale and composition of capital projects on the Bethesda Campus, and a review of the completeness, accuracy, and relevance of cost estimates for proposed capital projects.

CONTEXT

Investment and NIH-Wide Strategic Plan for Fiscal Years 2016-2020—Turning Discovery into Health

In 2015, NIH developed a comprehensive Strategic Plan designed to synchronize research program priorities and support forward-thinking decisions across the 27 institutes and centers (ICs) in response to the Congressional Consolidated and Further Continuing Appropriation Act of 2015 (P.L. 113-235, December 16, 2014).[1] The plan was not to replace individual IC plans but to develop a framework (Figure 6.1) to ensure that scientific discoveries advance health and that NIH upholds its scientific stewardship responsibilities. The 2016-2020 research Strategic Plan has the opportunity to serve as the primary catalyst in the development of Bethesda Campus capital facilities planning.

NIH Mission and Research Goals

The NIH intramural research program facilitates high-impact science in a variety of ways, particularly the following:

[1] NIH, *NIH-Wide Strategic Plan Fiscal Years 2016-2020*; hereafter "NIH-Wide Strategic Plan."

- It encourages unique approaches to difficult research challenges, with frequent collaborations outside NIH institutions and scientists.
- It houses the NIH Clinical Center (CC), the world's largest hospital dedicated solely to clinical research. The work of the CC links patient care with basic research discoveries and programs for the study of undiagnosed diseases and rare diseases and conditions.

The NIH-Wide Strategic Plan states that the mission of the organization is to "seek fundamental knowledge about the nature and behavior of living systems and to apply that knowledge to enhance health, lengthen life and reduce illness and disability." In order to achieve this mission, the plan identifies four goals:

- To foster fundamental creative discoveries, innovative research strategies, and their applications as a basis for ultimately protecting and improving health;
- To develop, maintain, and renew scientific, human, and physical resources that will ensure the nation's capability to prevent disease;
- To expand the knowledge base in medical science and associated sciences in order to enhance the nation's economic well-being and ensure a continued high return on the public investment in research; and
- To exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science.

The Intramural Research Program (IRP) that supports the currently adopted NIH-Wide Strategic Plan goals includes the following:

- To prevent dire impacts on individual and community health,
- To retain a world-glass biomedical workforce, and
- To remain competitive in the global biomedical research environment.

NIH-Wide (Research) Strategic Plan

The four interdependent objectives outlined in the NIH-Wide Strategic Plan to achieve its mission and fulfill its stewardship obligation (see Figure 6.1) are as follows:

- Advance opportunities in biomedical research,
- Foster innovation by setting NIH priorities,
- Enhance scientific stewardship, and
- Excel as a federal science agency by managing for results. (NIH 2015b, p. 9)

While the NIH-Wide Strategic Plan calls out the need "to develop, maintain, and renew scientific human and physical resources that will ensure the nation's capability to prevent disease," that document does not identify any specific building or infrastructure facilities, space utilization policies, or capital investment strategies that will strategically support the growth and desire to be in more "nimble," except through the annual Department of Health and Human Services (HHS) budget. It is unclear why the plan does not address the built environment, although it was suggested that because this is an enterprise-wide Strategic Plan, institutional facilities and capital needs were considered too minor of an issue to be called out. However, with respect to ensuring that NIH continues to prioritize the importance of capital facilities planning and reinvestment in existing capital assets, it was not evident to the committee that NIH leadership is aware that other major biomedical research institutions in the United States and internationally explicitly include specific capital investment requirements in their institutional strategic plans.

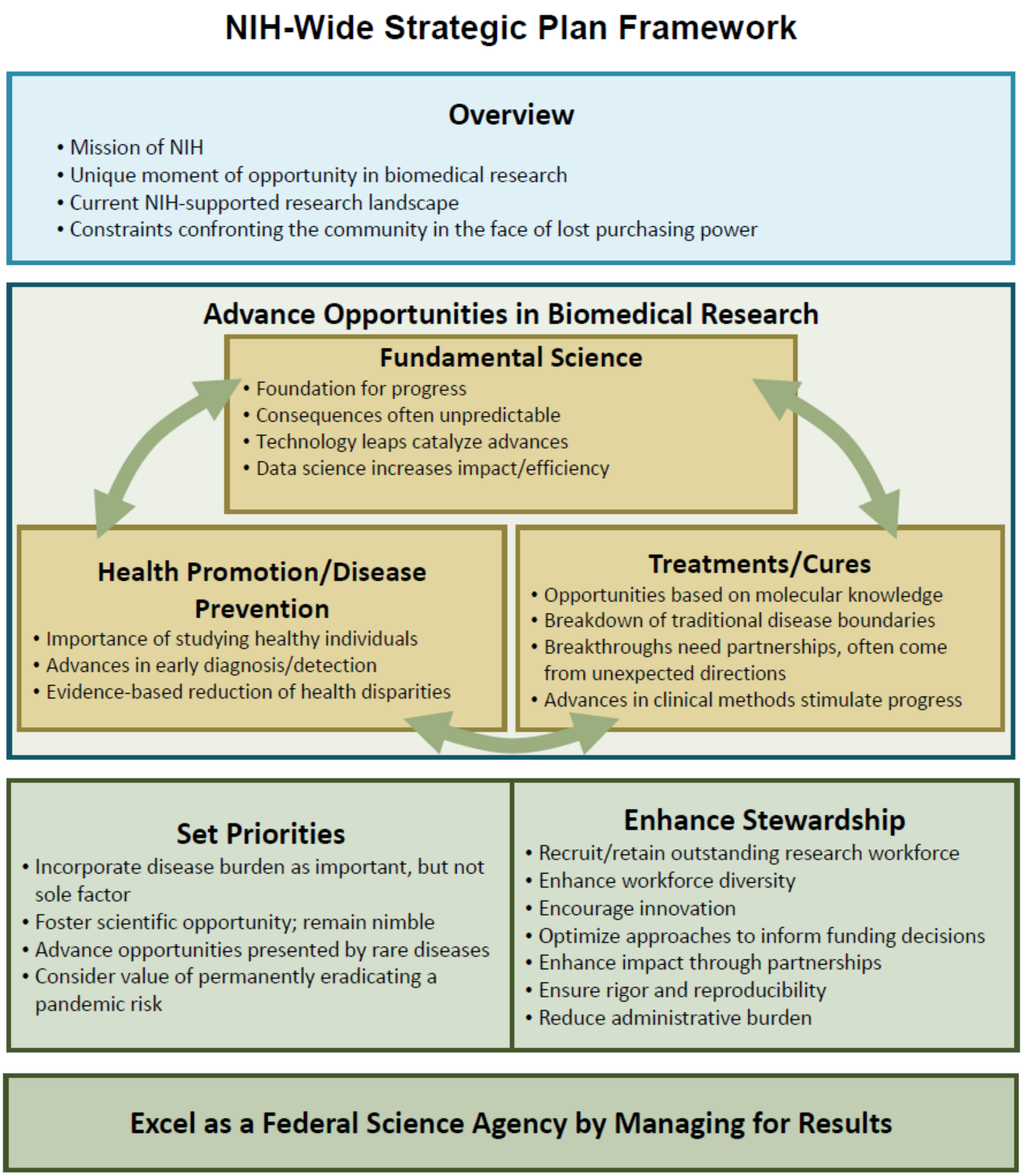


FIGURE 6.1 NIH-Wide Strategic Plan Framework. SOURCE: NIH (2015b, p. 2).

In addition, this committee did not see any evidence that NIH has developed strategic implementation plans or related capital asset plans that correspond to the NIH-Wide Strategic Plan. Most of NIH's competitor research organizations develop and integrate short-term (0-3 years), mid-term (3-9 years), and long-term (10+ years) capital facility plans linked to strategic research plans within their implementation documents. Such strategic implementation plans usually include needed facility and infrastructure assets, including details in terms of size and capacity, cost, timeline, and location, and how the facilities align with the research agenda. These proposed asset investments need to be analyzed and assessed on an ongoing basis, because rapid changes in science, fluctuations in funding and construction costs, changes in building conditions, and shifts in timelines all require that facility planning be tightly linked to short- and long-term research objectives. Developing proactive management practices that link strategic and facilities planning over time would help ensure that investments in facilities support the organizations' mission and goals and that NIH can fulfill its scientific stewardship objectives.

As noted in the April 2016 Clinical Center Working Group Report to the Advisory Committee to the Director (NIH ACD, 2016), there was "inadequate attention to capacity and prioritization: There is little scientific prioritization across ICs, and this becomes particularly problematic in the case of shared resources" (p. 14). That report further noted that there was "no independent entity to verify that engineering controls for high-risk facilities meet appropriate regulations or standards prior to or after construction" (p. 17). The findings of the report are evidence that the types of risks assumed by leading-edge clinical research and hospital operations generally differ from those associated with biomedical research.

Long-Term NIH Intramural Research Program

Intramural Research Program Strategic Plan

As outlined in the *Long-Term Intramural Research Program* report by the working group of the NIH Director's Advisory Committee (NIH ACD, 2014), the IRP's long-term strategic goals are to train the next generation of scientists and to support large research efforts beyond what is reasonably achievable in the extramural community. Specifically, the NIH Director requested that the working group "identify areas of opportunity and uniqueness that should be enhanced within the IRP, as well as approaches to ensure the sustainability of the IRP going forward" (p. 1).

The working group developed recommendations in the areas of research, training, infrastructure and facilities, workforce, and administration. In the category of infrastructure and facilities, the working group recommendations were to (1) develop more robust programs with the extramural research community; (2) increase accessibility of all "core" resources such as the Clinical Center (including unique equipment); (3) develop data and computing capabilities; and (4) evaluate the feasibility of a centralized bio-bank (NIH ACD, 2014, p. 6).

The working group acknowledged that these objectives may require long-term investments, as well as the flexibility to change direction in response to new scientific discoveries or public health needs. The report also stated that the IRP has an important role in supporting the full integration of the NIH biomedical research effort. This integration will require changes in the IRP structure and culture to support team science and local, national, and international collaborations, and will require world-class state-of-the-art research facilities. The working group emphasized that facility and research infrastructure need to be integrated and optimized, especially given the cost of technologically advanced core facilities, research animal facilities, and a high-throughput computational IT infrastructure. In addition, the working group affirmed the commitment to maintain a state-of-the-art clinical research facility such as the Clinical Center.

Given the global competition to recruit, train, and retain an increasingly diverse scientific workforce, the report and several other NIH planning documents conclude that the IRP needs to build and support a biomedical research ecosystem that is second to none. Therefore, implementation of strategies to ensure that the organizational structure, culture, and capital planning efforts promote a physical work environment that continues to advance team science is needed. The proximity of the ICs within the Bethesda Campus and region and proposed close collaboration with the extramural national and international community together present a unique opportunity to ensure the nation's continued global leadership in biomedical research.

MANAGING INVESTMENT

Comprehensive Master Plan—NIH Bethesda Campus

Four Priorities

In 2013, NIH developed an update to its 20-year Master Plan for the Bethesda Campus to serve as a tool for advancing NIH's long-term scientific mission. The document was titled *2013 Comprehensive Master Plan—NIH Bethesda Campus* (NIH ORF, 2013). During its discussions with NIH and its tours of the campus facilities and infrastructure, the committee observed that some aspects of the plan had been implemented, some revised, and still others not yet acted upon. The Master Plan identifies four priorities or strategies for implementation endorsed by the Facilities Working Group, which can be paraphrased as follows:[2]

- Advancement of NIH's strategic research initiatives,
- Replacement of aging physical plant,
- Resolutions to regional traffic congestion, and
- Reduction of NIH's leased facilities.

The 2013 Master Plan includes Master Plan Goals and Objectives. Goal I—"Foster innovative research to improve the nation's health"—identifies six specific objectives associated with the long-term physical development on the historic Bethesda Campus:

- Establish a comprehensive and coordinated approach to physical development of NIH that is based on cost-effective, incremental options for growth while ensuring orderly development of the campus.
- Stimulate interaction and communications among scientists and staff to enhance quality of research and opportunities for interdisciplinary collaboration through adjacency of uses and creation of formal and informal meeting and gathering spaces on campus.
- Create a flexible development plan that will allow for changing program needs in the future.
- Organize campus into research clusters, which will aide in applying high-throughput technologies to understand fundamental biology, to uncover the causes of specific diseases; translating basic science discoveries into new and better treatments; and reinvigorating and empowering the biomedical research community.
- New research buildings proposed in the master plan will be multi-institute and flexible to facilitate the creation of centers of science such as the Porter Neuroscience Center and new Immunology Center to further scientific collaboration.
- Consider potential impacts of changes in technology and advances in research processes. (NIH ORF, 2013, p. 1-31)

However, the application of the six objectives will likely continue to challenge NIH's current capital cost planning process due to the apparent broad and disorganized nature of planning requests received by the Office of Research Facilities (ORF), and in the future will likely require a more innovative and rigorous approach.

---

[2] The four strategies as the appear in the plan are as follows: Optimize use of NIH sites to support science enterprise; provide safe, modern research space; sustain/improve existing facilities by modernizing assets; and plan to reduce lease space costs by utilizing government owned facilities (NIH ORF, 2013, p. 6-67).

Advancement of NIH's Strategic Research Initiatives

As stated in the Master Plan, "NIH's mission is to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce the burdens of illness and disability." The Master Plan's vision is to promote scientific collaboration by organizing the campus into research clusters which will facilitate

- Applying high-throughput technologies to better understand fundamental biology and uncover the causes of specific diseases;
- Translating basic science discoveries into new and better treatments; and
- Reinvigorating and empowering the biomedical research community. (NIH ORF, 2013, p. i)

Although NIH does not anticipate significant growth in its science programs in the next 20 years, it does project changes in biomedical research that will require greater scientific collaboration across disciplines. This will require that research facilities be multi-institutional and flexible. It is anticipated that the creation of additional centers of science, such as the Porter Neuroscience Center and the new Immunology Center, will need to be constructed to enhance scientific collaboration. It is also projected that there will be more need for computational and systems biology facilities. These projected changes in science should drive the design and location of NIH's new and renovated biomedical research facilities.

Replacement of Aging Physical Plant and Reduction of NIH's Leased Facilities

Since NIH ICs do not expect to expand scientific programs, personnel, or space in the next 10 years, the Master Plan addresses two additional priorities: replacing its aging physical campus and reducing operating costs by reducing the number of leased facilities.

In addition to developing a campus Master Plan that addresses future scientific goals, the Master Plan also highlights the needs of an aging physical plant where existing facilities over the next 20 years may no longer be able to support the organization's scientific mission. NIH uses several independent assessments to evaluate the physical conditions of the campus's facilities, including the following:

- The Federal Real Property Council's Performance Measures to evaluate its existing facilities with respect to mission, utilization, operating cost, condition, and disposal/remediation;
- The NIH Buildings and Facilities Model to aid in evaluating program impact, functional obsolescence, and facility impact; and
- Sustainability goals and sound stewardship practices, such as adapting and reusing historic buildings.

Based on these assessments, NIH estimates that 11 percent of gross square feet (GSF) of its research square footage marginally accommodates existing research needs and 5 percent is obsolete. These older research buildings' structural systems and configurations cannot be readily updated to accommodate current research space as currently configured and mechanical systems requirements.

The Master Plan also addresses the federal requirement that all agencies strive to reduce the number of leased facilities to reduce operating costs. Therefore, the plan includes strategies to renovate outdated research facilities and build new administrative space to accommodate employees residing in leased space on campus.

Resolutions to Regional Traffic Congestion

The Master Plan also gives high priority to addressing the region's traffic congestion. While NIH's employee growth has contributed to the traffic congestion, the Bethesda Central Business District (CBD) and the Friendship Heights CBD have grown still faster. The Master Plan includes the Transportation Management Plan, which outlines short- and long-term strategies to mitigate traffic congestion.

Implementation of Four Priorities

To address the above-mentioned priorities, contingent on future budgets, opportunities, and policy, the Master Plan outlines the following solutions.

Research

- Organize the campus into five research clusters to facilitate and nurture collaboration and create opportunities for development of multi-institutional centers and address other trends such as computational biology.
- Accommodate leased laboratories and the lack of modern research facilities by constructing 1.6 million GSF of research space. Five of the new buildings are planned to house intramural research.
  - Stabilize 500,000 GSF of space in the old Clinical Center complex to prepare it for adaptive reuse, in addition to the 2,900,000 GSF already scheduled to be renovated.
  - Replace housing and care facilities for animals with state-of-the-art facilities that satisfy modern design, accreditation, and program requirements.

Administration

- Bring all administrative functions back to the Bethesda Campus and reduce operating costs and enhance scientific collaboration.
  - Construct 775,000 GSF of administrative and support space and three new parking garages.

Utilities

- Continue the upgrade and modernization program for utilities and infrastructure, particularly the central heating and refrigeration plant, campus steam, chilled water, and electric power distribution systems.
  - Consolidate utility support and service functions in proximity to Building 11 and to the far south end of the campus.

Campus Environment

- Cluster administrative and biomedical research education functions in close proximity to the Medical Center Metro Station.
- Construct expanded childcare facilities and other amenities, including small-scale retail and food services.
- Enhance the natural buffer zone around the periphery of the campus by removing surface parking and increasing landscape plantings.
- Reduce pedestrian conflicts by constructing elevated pedestrian walkways and tunnels, and build parking garages within a 5-minute walking distance to employees' workplaces.
- Enhance the Bethesda Campus environment by creating a series of development guidelines.
- Continue to develop a Transportation Management Plan that outlines short- and long-term strategies to mitigate the projected campus workforce increase of 3,000 employees and contractors.

NIH 2013 Comprehensive Master Plan—Bethesda Campus and Integration with the NIH-Wide Strategic Plan for Fiscal Years 2016-2020

As NIH implements its Master Plan, a few items should be considered to ensure that the plan remains relevant and adds long-term planning value to the institution. Establishing integrated proactive management practices that link the institution's Strategic Plan and facilities planning efforts could facilitate timely updates and success of the plan.

Changes in Research Strategic Goals

The 2013 Master Plan incorporates the goals and objectives of NIH-Wide Strategic Plan. As the Master Plan is implemented, it will be important to ensure that it continues to reflect and adapt to changes in NIH's strategic goals. As stated in Chapter 2, science is changing at a rapid and unpredictable pace. These ongoing changes will affect NIH's existing programs, organizational structures, budgets, workforce, and myriad other elements, resulting in the need to periodically reassess the strategic initiatives and reconsider their effects on the plan. Because many of these changes may result from unforeseen national and global factors, the committee believes that input from both internal and external experts would be beneficial.

Space Utilization

Continuing to optimize space utilization of existing and new facilities is critical to long-term planning. As technology changes, existing standards for laboratory, research support facilities (e.g., animal facilities), and administrative space will change. The existing process that allocates space to separate ICs will make it increasingly difficult to assess whether space is optimally used and to develop long-term space need projections. While NIH is projecting no increase in its research programs for the next 20 years, annual reassessment of space utilization is necessary to optimize the daily use of facilities, identify swing space, and project long-term facilities' needs.

In addition to developing long-term plans for animals and data facilities, a plan for the Clinical Center might be beneficial. Over the next 5 to 10 years, the nature of the patient care and research activities may change significantly, and the Clinical Center's capabilities will need to adapt, especially if the type of patient volumes change (such as the trend toward increased outpatient care), and if external collaborations increase.

Given the space utilization and planning challenges to the current Bethesda Campus, NIH might consider multiple different approaches to accommodate increases in on-campus space needs. For example, given the scale of leased space across Montgomery County and in adjacent areas currently and over the next 5 to 10 years, NIH might consider increasing the building density on the Bethesda Campus, collaborating with nearby organizations (e.g., the Walter Reed National Medical Military Center), or accessing nearby land to enable an extension of the NIH Bethesda Campus operations, ensuring easily accessible and reliable transportation between the new area and the historical site.

Increasing Partnerships

Partnering with other public and private organizations has been identified in the NIH-Wide Research Strategic Plan as a high priority. It was noted that increased partnerships would not only enable NIH to make maximum use of finite resources but they would also advance science and help fulfill NIH's mission. Strategies were identified in the Strategic Plan to continue to advance transdisciplinary knowledge and foster new collaborations through partnerships. Therefore, it is important that the Master Plan have the flexibility to address items such as increases in clinical facilities, access to high-end instrumentation/core facilities, temporary utilization of laboratory facilities by external researchers, and current constraints imposed by existing security measures.

Surrounding Community

As outlined in the Master Plan, changes in the surrounding community will continue to affect the Bethesda Campus. The community's strategic goals, corresponding NIH Master Plans, and population growth projections for the region will impact the campus. As articulated in the plan, the positive economic growth of the surrounding business communities has resulted in housing and traffic congestion. It is essential that NIH continue to build relationships and partnerships with the community to address these issues and to monitor changes over time. These relationships are beneficial in resolving community concerns, including the impacts of increased capacity, construction, noise and pollution.

Along these lines, there also has been very strict security instituted around the Bethesda Campus in response to the September 11, 2001, terrorist attacks. Unfortunately, the security measures generally exclude public access to the National Library of Medicine and the Natcher Conference Center, even though these entities are uniquely public-facing. Planning could examine new alternatives to ensure easy public access to resources on the Bethesda Campus to enhance relationships with the community.

Funding

The Master Plan and the NIH-Wide Research Strategic plan report that the lack of funding for strategic and facilities initiatives has hampered and will continue to hamper short- and long-term facilities planning and implementation on the Bethesda Campus. Therefore, it is essential that the Master Plan and NIH's capital plans—the Buildings and Facilities (B&F)/Nonrecurring Expense Fund (NEF)-Funded 5-Year Plan) be flexible and capable of adjusting to capital funding and priority shifts. (The funding appropriated for NIH does not ring-fence or otherwise separate capital budget dollars from operating budget dollars.) In addition to submitting requests to Congress for capital and renovation dollars, NIH could, the committee believes, continue to explore alternative sources of funding such as private development funds,[3] public-private partnerships,[4] and joint federal projects to increase funds needed to address critical master planning issues.

A key challenge for the future built environments of all biomedical research enterprises is how to best integrate strategic programmatic objectives in the context of perpetual limited capital resources, the need for efficient space utilization, and the severe challenge of accelerating deferred maintenance of building systems and site infrastructure. These facility and infrastructure assets are key to effectively supporting the research enterprise as it grows and changes, and as it continually adapts to changes in local and regional physical planning constraints in concert with the key regulatory and compliance requirements.

Leading academic and other research organizations increasingly integrate planning for operating and capital resources, since those organizations must now conduct appropriate financial due diligence, establish long-term planning horizons, and engage in much more rigorous cost/benefit analytics related to a total cost of stewardship perspective. These organizations leverage the value of every dollar through emphasizing highly functional and productive research and instructional environments, energy efficiency, staff and faculty operating efficiencies, institutional carbon reduction, and other sustainability and disaster resilience objectives. The values of these elements are explicitly estimated and verified at each stage of the planning, design, renewal, and replacement processes for every facility and infrastructure asset.

---

[3] See, for example, The Children's Inn at NIH, "Corporate and Foundation Partners," https://childrensinn.org/get-innvolved/corporatepartnerships/, accessed July 23, 2019.

[4] See, for example, NIH, "Accelerating Medicines Partnership," https://www.nih.gov/research-training/accelerating-medicines-partnership-amp, accessed July 23, 2019.

A longer, 10-year capital plan for NIH—currently there is the B&F/NEF-Funded 5-Year Plan discussed in Chapter 4—would have the opportunity to represent the long-term aspirations of the organization, including researchers, staff, and stakeholders. A successful long-range capital plan typically incorporates a flexible (not site specific) land use regulatory framework affecting a research campus, integrated with the institutional strategic scientific plan developed by the senior leaders of the research enterprise. To remain nimble in the scientific research environment, the built environment must remain equally nimble and flexible so that it can appropriately respond to future opportunities.

Capital Repair and Improvement—Current Reinvestment Approaches

The current NIH capital federal appropriation strategy, as an Operating Division of HHS, is to increase capital reinvestment resources to "repair," or for "repair-by-replacement" (HHS, 2006, pp. 1-17), or for "improvements (Renovations/Alterations)" (pp. 1-11), or for a hybrid plan that may regularly combine some of each on an ongoing basis. As stated previously, the normal life expectancy for major building systems such as mechanical, electrical, and roofing is approximately 30 years. Due to the limits and inconsistency of federal funding availability, the replacement of many of these systems on the Bethesda Campus has been deferred—creating a significant and growing backlog of capital assets reinvestment or a decision to replace or remove the capital asset. These reinvestments are defined in the HHS Facilities Program Manual Volume I and are identified as "repair and improvement" capital funding requests, as opposed to "maintenance and improvements" requests. Line item projects (construction, improvements, or repairs) are also requested, which may, if funded, contribute to the reduction of the Bethesda Campus deferred maintenance backlog.

At this time, the ORF manages multiple federal funding sources annually for these types of capital reinvestments to sustain the Bethesda Campus research enterprise. (See the discussion in Chapter 4, in section "Funding for Capital Projects.") Based on information received from ORF staff during open session presentations to the committee on September 25, 2018,[5] with additional details provided to the committee subsequent to the presentation, it appears that the ORF identifies and prioritizes specific repair and improvement projects annually, and perhaps as often as quarterly, based on regular meetings among ORF maintenance and operations subject matter experts and other technical staff.

The current tactical management approaches to reduce the deferred maintenance backlog include (1) increasing capital funding requests with a focus on supporting the current annual building system replacement prioritization plan; (2) continuing comparative financial and related cost-benefit or "highest and best use of limited capital resource" evaluations of renewal versus replacement of buildings (for example, continue to "improve" portions of individual buildings by focusing on a 5-year-plus planning approach, versus deferring improvements in multiple buildings based on probability of building replacement in future years); or (3) continuing reinvestment in the campus site infrastructure by use of energy and other utility cost savings or cost avoidance strategies. In Chapter 4, the committee nonetheless recommends first funding long-term infrastructure projects from among the list of such already identified by NIH and totaling approximately $700 million (see Recommendation 4.1).

Current Capital Cost Planning at NIH-BC

Cost estimating and planning for high-performance biomedical research facilities and infrastructure is increasingly being scrutinized at leading research organizations. Due to the high capital costs associated with developing major new research buildings, efforts to avoid or defer significant new capital and

---

[5] Jim Lewis and Dan Cushing, NIH Office of Research Facilities, Question and Answer session with the committee, September 25, 2018.

operating costs to operate and maintain the new facilities are active; these efforts are described in an Education Advisory Board study as "breaking the cost-to-grow curve."[6]

Leading research organizations are also exploring different strategies to better manage capital and operating cost expenditures for new facility and infrastructure assets. The August 2017 consensus study report of the National Academies of Sciences, Engineering, and Medicine, *Strengthening the Disaster Resilience of the Academic Biomedical Research Enterprise: Protecting the Nation's Investment* (NASEM, 2017, p. 311), noted

> Two recurring capital cost reduction strategies in the academic research enterprise have been increased research space utilization or the redesign of existing research space to improve productivity outcomes. There is also renewed focus on the adaptive reuse of existing research or nontraditional research facilities, particularly for those research programs with a demand for more computational space and less wet laboratory space, programs desiring more open office space, or programs shifting from the bench to share core research facilities.

As noted earlier, the document, *2013 Comprehensive Master Plan—NIH Bethesda Campus* (NIH ORF, 2013), specifies in Goal I the need to "Foster innovative research to improve the nation's health." The last two objectives in that goal (i.e., multi-institute, flexible new research buildings and adaptability to changing research processes) suggest that the needed facilities and infrastructure will require more in-depth planning and costing due diligence to enable nimble shifts in facility and space configurations. Among other factors, these new facilities will require consideration of structural flexibility, as well as the adaptability of information technology services and thermal management infrastructure. The requirements for these high-performance laboratories and work environments are often state-of-the-art, and therefore have limited cost data benchmarks in the industry. In contrast, standard or traditional building designs can use widely available cost data and benchmarks using common parameters (such as cost per square foot or linear foot) that can be applied during the earliest design development. A major challenge for cost planning for the NIH state-of-the-art facilities is the lack of available cost benchmarks during the earliest design phases and under limited investigation of the specific conditions of the proposed capital project.

Current NIH IRP project-specific capital cost models appear to be prepared in response to requests received from a wide range of sources within the Bethesda Campus and from NIH facilities located off-campus. Figure 6.2, "Facilities Decision-Making Process," excerpted from the *2013 Comprehensive Master Plan—Bethesda Campus*, characterizes the multiple and complex planning pathways in place for the NIH Intramural Research enterprise (NIH ORF, 2013, p. 6-66). The diagram raises questions about the ongoing decision-making procedures, particularly to establish and enforce priorities and adjudicate disputes.

In general, the ORF responds to the cost model requests from the Facilities Working Group (FWG), the Space Recommendation Board, and individual ICs. The early project cost planning processes appear to be funded by (1) an individual IC or IC program; (2) ongoing HHS authorizations for B&F; (3) the HHS NEF; or (4) the ORF annual operating budget. The Office of Research Facilities' Division of Facilities Planning, among many other responsibilities, also develops the NIH Lease Space Plan, the NIH Strategic Facilities Plan, and the Building and Facilities (B&F) budget plan. The FWG is described further in Chapter 5, in the section "Process by Which Projects Are Planned and Evaluated."

The ORF appears to provide cost projections for all projects included in the regularly evolving NIH Condition Index, Sustainment, and Improvement Funding Needs Plan, and approved NEF-funded[7] campus-wide transportation, utility, and information technology infrastructure improvement projects, which appear to be a significant portion of capital cost projection activity. These cost estimates are needed throughout the year, and particularly when the B&F funds are allotted quarterly.

---

[6] Education Advisory Board, "Maximizing Space Utilization," https://www.eab.com/research-and-insights/academic-affairs-forum/studies/2010/maximizing-space-utilization/the-space-utilization-imperative/breaking-the-cost-to-grow-curve, accessed February 6, 2019.

[7] This source of monies is described further in Chapter 4, in the section "Funding for Capital Projects."

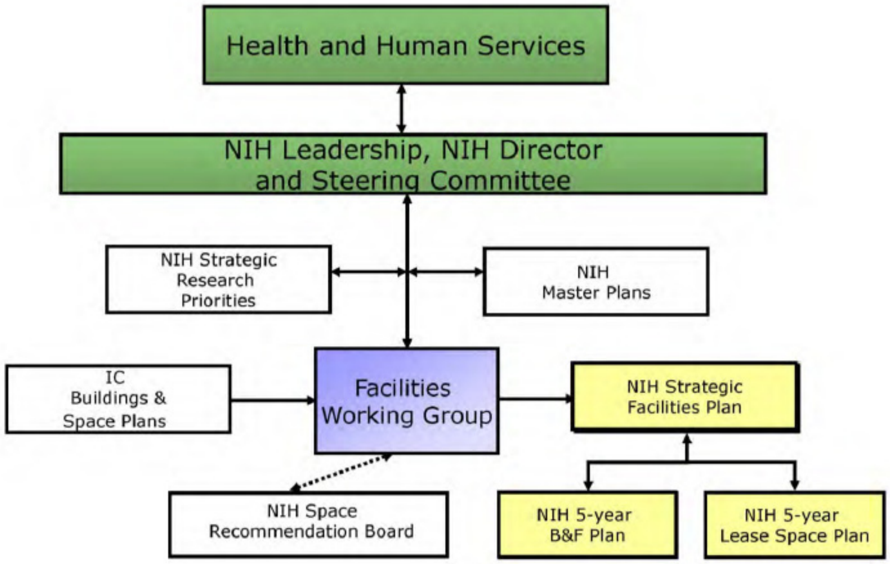


FIGURE 6.2 The facilities decision-making process. The Facilities Working Group (FWG), as can be seen here, lies at the nexus of several organizational units and processes. The director of the Office of Research Facilities is a nonvoting member of the FWG. NOTE: B&F, Buildings and Facilities; IC, institute and center. SOURCE: NIH Office of Research Facilities (2013).

Uncertainties and risks in capital planning for state-of-the-art research facilities include the higher cost than typical buildings, the lack of easily available standardized cost benchmarks, and complex capital cost planning requests. For these reasons, the ORF should consider establishing a clear and consistent annual schedule for review of capital project priorities and estimated costs.

NIH Bethesda Campus Project Capital Cost Factors

Underlying the NIH capital project cost assumptions are the critical issues related to complying with the requirements of the National Capital Planning Commission, the National Historic Preservation Act, Executive Orders, HHS plans, Principles for Federal Leadership in High-Performance and Sustainable Building, Fire and Life Safety, and the other national model building codes and standards (including seismic performance improvements and special provision for seismic loads in the research environment) and significant interagency federal security protection design requirements. Other core assumptions used by NIH for each capital project cost model include (1) appropriate construction cost escalation factors to mid-point of the projected construction schedule; (2) a traditional design-bid-build construction procurement strategy (not potential alternative project delivery systems, including design-build, construction manager at risk, or cost-plus type construction delivery agreements); and (3) owner contingency factors, which are variable based on each level of the project planning phase completion.

It is also important to note the geographic factors in the Washington, D.C., metropolitan area, which may impact design and construction delivery costs due to marketplace conditions regarding the volume and timing of regional construction activity and impacts of specific labor availability and cost. Of special note, NIH-owned facilities are required to follow the latest requirements of the NIH Design Requirements Manual (DRM)[8] for new or renovated biomedical research and animal care facilities. The NIH DRM includes prescriptive requirements that intend to enhance the safety, energy efficiency, and indoor air

[8] NIH, 2016, *Design Requirements Manual: Biomedical and Animal Research Facilities Design Policies and Guidelines*, https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx.

quality, as well as support cost-effective maintenance and improved building systems life cycles, while maintaining operations of biosafety level 1-4 facilities, animal care facilities, and tanks during normal conditions.

The 2016 edition of the NIH DRM also contains specific provisions for improving the resilience of the built environment during disasters—including utility service disruptions—by requiring a project-by-project risk assessment that considers the consequences of systems failures and development of appropriate and affordable mitigation actions. The provisions include a wide variety of requirements related to facility location, arrangement of space, location of critical equipment and utilities, and fail-safe control systems with the goal of mitigating the potential loss of critical building systems services loss in the clinical, laboratory, or animal care facilities.

According to material provided to this committee, NIH appears to have higher cost adjustment factors than many of its peer institutions due to a range of factors, including the location construction cost factors in the Washington, D.C., metropolitan region, and NIH and federal compliance requirements noted above. The committee believes that this makes a compelling case that NIH will have construction costs higher than those of other organizations not so constrained.

Capital Project Cost Projections—When Are Projections Provided?

The HHS Facility Project Approval Agreement (FPAA) documents a specific capital project with a concise summary of information, including projected cost. This agreement, if funded in the annual HHS capital budget submission, serves as the basis for a future commitment by NIH to meet the requirements noted: scope, schedule, capital cost project, and narrative justification.

The deliverable for the "Pre-Project Planning Phase" by the NIH ORF's Division of Facilities Planning provides the data and information for inclusion in the NIH final FPAA Form 300 submission. The Facilities Working Group determines the annual recommendations for funding. FWG's recommendations are forwarded to the IC directors, who review the FWG's capital projects recommendations at an annual budget review meeting. It appears that the FWG, in concert with ORP, directs the level of cost model development completed or to be completed by the ORP Division of Facilities Planning based on three categories:

- Projects having sufficient information with a "program of requirement's" (POR) and cost estimates to be considered for funding in an annual B&F Plan.
- Projects that are being studied in a current fiscal year that could be proposed for design in the next annual B&F Plan. Priority dictates the order in which the POR and cost estimates are completed.
- Projects that need further study before they are ready to be designed. Priority dictates the order in which studies are accomplished. (NIH ORF, 2013, p. 6-68)

The FPAA Form 300 is not a detailed cost estimate and represents only a concise one-page summary of more detailed cost projections including direct construction costs, construction cost escalation, construction contingencies, and indirect costs (including design consultant services, land acquisition costs, permitting and associated regulatory costs and fees, furnishings-furniture-equipment, project management costs, and project contingencies).

Table 6.1, provided by ORF staff, is intended to identify prioritization scoring as well as status of current preplanning actions. The table identifies three proposed capital project categories[9] for NIH's "Projects Proposed in Building and Space Plan Process in Spring 2017": Section A: Complete POR, EIS, and IGE; Section B: Incomplete POR, EIS, and IGE; and Section C: Minimal Definition. Neither project capital cost projections nor potential fund sources were included in this Scoring Table as a decision making component when this blended prioritization and planning status table was created in spring 2017 by the ORF.

[9] These categories, as well as the scoring and ranking system that populations them with projects, is described in detail in Chapter 5, in the section "Process by Which Projects Are Planned and Executed."

TABLE 6.1 Projects Proposed in Building and Space Plan Process in Spring 2017

Campus	B&F Line Item Projects	B&F Section	Proposing IC
Section A: Complete POR, EIS, and IGE			
BC	Addition to the CRC to house Surgery/IR and RADIS/DLM—construction	A	CC
BC	Center for Disease Research (including vivarium to replace Building 14/28)	A	ORF
BC	Electrical power reliability for the Clinical Center	A	ORF
BC	Renovate building 6A as office, once empty	A	ORF
FC	Integrated Research Facility—construct a 271,000 GSF consolidated vivarium facility for relocation of animals and employees from 32 buildings to house the NCI research colonies and animal research support services at Frederick; also construct new utility plant at the south portion of the campus	A	NCI
RML	ORF/ORS/NIAID support building	A	ORF/ORS/NIAID
RTP	Site utility loop—construct	A	ORF
BC	Replace Clinical Center patient and visitors parking	A	ORF
RTP	Computational Science Building	A	NIEHS
RML	Comparative Medicine Center	A	NIAID
BC	Addition to Vaccine Research Center (Building 40)	B	NIAID
Section B: Incomplete POR, EIS, and IGE			
BC	Building 10 West Distal Wing (H&J) renovation	B	ORF
BC	Building 10 East Distal Wing (A, B, C, & D) renovation	B	ORF
BC	Building 10 ACRF renovation	B	ORF
BC	Additional cell processing	B	ORF
BC	Convert G Wing to clinical offices	B	ORF
BC	Building 31 replacement, waste management facility, grounds maintenance, police station, parking structure, and associated infrastructure projects	B	ORF
BC	Renovate Building 1	B	ORF
BC	New South Laboratory, adaptive reuse of Buildings 4, 5, 8, 30, and 41; Frederick, new parking structure, and associated infrastructure projects	B	ORF
BC	New Central Laboratory and associated infrastructure projects	B	ORF
RML	BSL-2 and 3 Research building (combination or previously requested research space)	C	NIAID
BC	New/expanded NIH Data Center for expanded scientific computing	B	CIT
Section C: Minimal Definition			
BC	Renovate Building 29A as lab and animal facility	C	ORF
FC	Construct a 268,000 GSF laboratory facility to house the current and developing research/clinical programs to replace aging and outdated laboratories in Frederick	C	NCI
BC	Renovate Building 29 as computational/dry lab	C	ORF
BC	Continuing requirement for an additional MRI bay in the Clinical Center	C	NINDS
BC	In future Building 45 addition, provide future NCBI space requirements for staff growth and expand collections space to accommodate growth of collection material, driven by the increase in genomics research and high-throughput technologies	C	NLM
FC	Construct a 288,400 GSF four-story parking garage on the north portion of the Frederick Campus to support the current and developing research/clinical programs	C	NCI
BC	New construction/addition to facilitate round-robin renovations in Building 10	C	ORF
BC	Central quadrangle	C	ORF

NOTE: Acronyms are defined in Appendix K.

Capital Project Cost Projections—Accuracy and Relevance

The capital cost for a project, above and beyond the value of the project to advancing the scientific mission, is a critical determinate in a research institution's decision to pursue funding.

Cost planning is a rigorous discipline and requires large volumes of current data and senior-level professional expertise to achieve a high level of accuracy. Regardless of the phase of the design and construction process—from early conceptual predesign to a design that is poised to be competitively bid—cost matters to all parties. Effective capital cost planning represents a reflection of an institution's credibility and viability. The example of cost planning for capital projects by the Bureau of Reclamation is discussed in Box 6.1.

To respond to the committee's charge to evaluate at a high level the completeness, accuracy, and relevance of cost estimates at the Bethesda Campus, the ORF provided the committee with approximately 70 conceptual capital budget documents (as defined in the May 19, 2006, HHS Facilities Program Manual Volume I (HHS, 2006) as "preproject planning"-level materials) associated with proposed NIH capital projects. However, these documents are not considered detailed cost estimates because they contain limited details on the scope of the proposed capital construction, limited references to sources of the direct construction costs (professional cost planners, architects, RSMeans, or the Department of Defense Cost Estimating Guide, or other), or detailed construction costs based on recognized Uniformat or CSI cost model formats.

The committee concluded that the preproject capital planning documents, in general, appear to be prepared by ORF staff consistent with the following: (1) current HHS Facilities Program Manual Volumes I and II for "Costing Repair Needs" or "Opinions of Cost" (HHS, 2006, pp. 2-30 and 2-36); (2) Department of Energy GP Checklists; (3) additional HHS Facilities Program Manual required documents, including Project Definition Rating Indices; (4) Project Delivery and Contract Strategy evalulations; (5) NIH Nonrecurring Expense Fund Project Budget Justification narratives; (6) Appropriation/Obligation Budget summaries; and (7) an NIH ORF "Capital Cost Template" based on a basic Microsoft Excel spreadsheet.

The sample of NIH preproject planning capital cost, scope, and schedule planning documents provided to the committee indicate the use of consistent general capital cost categories defined by the HHS Facilities Program Manuals and included, if required, at a summary level in the HHS Form 300—Facility Project Approval Agreements (FPAA). Use of the HHS Form 300—FPAA is mandatory for Deputy Assistant Secretary for Facilities Management and Policy [DAS/OFMP] or HHS board-approved projects. The NIH Director has received the delegated authority and is responsible for the approval of construction and improvement projects under $1,000,000, and all repair projects under $3,000,000 (HHS, 2006, p. 2-1).

These summaries serve as the critical NIH capital budget request submission document reviewed during the annual HHS Capital Facilities Review Process: "The FPAA will serve as the project justification, and as such shall be submitted as part of the HHS budget formulation process" (HHS, 2006, p. 2-2). Individual FPAA project "Deviation" and "Revision" submissions are also regularly provided by NIH as part of the HHS Capital Facilities Review Process by use of the form "Changes to Facility Approval Agreement" (HHS, 2006, p. 2-10).

An objective comparative review of the cost planning-related documents provided to the committee indicates compliance with the broad categories of total project cost requested by the FPAA. However, the FPAA capital cost information appears to be informed, as noted earlier, from multiple, different, and potentially inconsistent data sources as noted in an ORF "Capital Cost Template." This total capital project cost template is typically developed by the ORF project officer, often with the support of consulting professional engineers, architects, and construction and equipment cost planners.

BOX 6.1
The Bureau of Reclamation

As a nonmilitary federal agency managing a consistently large volume of complex and challenging capital projects, the U.S. Bureau of Reclamation views the effective preparation, review, and proper management of cost estimates to be key to the success of their mission. They identify that benefits to their cost planning activities will be continuous improvement of the completeness and consistency of their cost estimates. They identify that the benefits that will accrue to the bureau are not simply the sense of successful project accomplishment for those involved but also improved ability to maintain credibility with their partners, and perhaps most important, sustain the bureau's national, regional, and local credibility.

The Bureau of Reclamation's Manual (FAC 09-01 Directives and Standards) addresses the development of cost estimates. There are six levels of cost estimates used to support the Bureau's capital projects, as follows:

1. Preliminary
2. Appraisal
3. Feasibility
4. Percent [100%] Final Design—Post-Project Authorization
5. Prevalidation of Final Funding
6. Independent Government Cost Estimate

Cost estimates are typically developed in the chronological order shown above, and each supersedes the previous one. They differ in degree of detail, refinement, use, and confidence, and are dependent upon the amount of certainty contained in the available engineering and geological data, and other factors (e.g., environmental considerations, land acquisitions costs, and procurements methods) known at the time of preparation of the cost estimates.

The sequencing of the various levels of cost estimates is standard; however, the time frame for these cost estimates within the various project stages may vary depending on the project and its objectives. Because of program requirements and management decisions, some levels of estimates may not be required.

TABLE 6.1.1 Various Stages of a Reclamation Project and the Associated Levels of Cost Estimates

Project Status	Project Stage	Level of Cost Estimate Produced
Planning	Planning	Preliminary
		Appraisal
		Feasibility
Construction	Final design	Percent final design (updated feasibility)
		Prevalidation of funds
	Solicitation	Independent government cost estimate (award)
	Construction	Independent government cost estimate for contract modifications
Operation and maintenance	Operations	One or more of the previously identified estimates

Inconsistent metrics appear to exist within key NIH Capital Cost Template cost model line items. These inconsistencies do not appear to be based on typical variables, including geographic factors (e.g., seasonal or clinical or research operation schedule requirements or labor conditions impacts), construction cost scale of a project, project duration due to construction or regulatory entitlement processes, capital cost escalation factors, project complexity, construction phasing, acquisition of major equipment components, or other variables among individual capital projects.

Key inconsistent metrics within the NIH Capital Cost Template include the application of discrete and benchmarked annual escalation and geographic variability factors, the project design and construction contingency factors, "building commissioning" (Cx) and information technology systems and support (i.e., communications and information technology) factors, major fixed and movable equipment market-rate cost projections, and construction quality control and management factors, among others. These inconsistencies, particularly with the application of large project contingencies, are often a consequence of insuffficent clarity of project scope and schedule during the preplanning process.

The NIH ORF Capital Cost Template for the Bethesda, Rocky Mountain Laboratory, and other IRP sites serves currently as the critical baseline financial planning document utilized by NIH staff who are most directly responsible for leadership and management of the preplanning phase capital cost model. The degree to which these total project cost models are accurate and comprehensive at the preplanning stage of a project may ultimately represent NIH's leadership commitment to the scientists, staff, patients, and the nation by providing the most informed, credible, and defensible financial projection of each project's capital need to sustain NIH's missions. Clear decision making at these early planning stages has been demonstrated to be extremely important in mitigating finanical (e.g., budget, scope, and schedule) risks for individual capital projects while concurrently enhancing insitutional capital financial management credibility. Best practice evidence in capital project management typically identifies the critical role played by a rigorous, integrated, and comprehensive design preplanning process—successfully represented in the POR deliverable—as fundamental to successful investment of capital that will create the functional and inspirational built environment to enhance innovation and collboration within the research enterprise. The successful integration of scientific program leadership with the built-environment technical subject matter experts often begins at this first and earliest stage of the capital project planning process. The committee's findings regarding the planning process and the completeness, accuracy, and relevance of the cost estimates appears at the end of the chapter.

Context for the Critical Importance of Accurate, Comprehensive, and Integrated Capital and Operating Cost Planning

Following recovery from the Great Recession of 2008, the trustees of many public and private academic biomedical research institutions adopted financial sustainability action plans, created detailed capital investment master plans, and integrated the two into one comprehensive financial plan (Motley, 2012). The integration of these traditionally separate budget-planning processes was recognition that institutional financial health is the critical prerequisite to sustaining excellence, innovation, and discovery within the research enterprise. Integrating the facilities and space needs of multiple schools, departments, or, for NIH, institutes and centers, into one comprehensive financial annual planning and forecasting process offers the opportunity to create more transparent and rigorous criteria for financial (operating and capital) resource allocation prioritization. The committee believes that the development and application of consistent and credible capital cost data is critical to sustaining the NIH intramural research program's short-, mid-, and long-range capital plans.

To create a credible and useful capital financial planning framework for specific potential capital projects, capital planning experts typically seek as much accurate and complete information as possible regarding the research program's activities from the specific research program leaders (termed by the ORF as the program of requirements, or POR), benchmarking equivalent programs at different research institutions, and informal or formal peer reviews through site visits and other investigations. The translation of a research program's activities at a preliminary and early stage of development into a built environment that does not yet exist is extremely challenging, but critically important to the capital plan's institutional prioritization processes. Not all "proposed" scientific initiatives/projects and their potential space and infrastructure needs can be subject to lengthy and costly (in terms of both scientific staff time and dollars) assessment; at the same time, there must be sufficient information to allow the institution to credibly identify and evaluate the capital requirements.

Capital planning and decisions regarding capital resource allocation require sound projections of the space, equipment, and infrastructure needs required and the financial costs. Without in-depth understanding of program operational requirements, there is a high probability of inaccurate capital cost projections and the resulting significant negative impacts (e.g., reduction in project scope, delays in project completion, lost revenue, and other opportunity costs, including staff recruitment and retention impacts), which may be revealed only at later stages of an approved project's development. Owing to the critical need to understand the science as much as the technical facilities requirements in creating conceptual capital budgets, many institutions are increasingly identifying scientists and program staff, not the more typical model of architects and engineers, to lead their capital planning activities. For example, Dr. S. Lui, former U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) principal investigator, currently directs the USDA's principal intramural scientific research agency's capital planning activities with support from his technical staff who possess expertise in facilities management and operations (see Box 6.3).

Under the increasing accountabilities contained in the results-oriented financial plans of the nation's academic and governmental research enterprises, accurate capital cost projections and identification of all targeted capital fund source(s) opportunities and commitments become "mission critical" processes that, if demonstrated as credible through professional peers and peer agency reviews, can only deepen NIH's national and global support and viability. The indispensable links among capital cost, operations of the research enterprise's programs, and time (when the physical solution will be available) should be recognized in a comprehensive capital plan.

As noted in earlier chapters of this report, and as a critical first step, the ORF has successfully identified and categorized the critical assets and vulnerabilities in the Bethesda Campus built environment[10,11]—shared with the committee as the CISIP[12] mentioned earlier in this chapter. At the same time, the Government Finance Officers Association identified the most challenging components of any institutional or corporate capital planning process: identifying priorities for investment and funding sources that will implement the plan (Kavanagh, 2007). Without targeted or realistic capital resources identified or committed, an institutional capital plan that includes all "great ideas" becomes more of a "wish list" that may not be credible to the research enterprise or its funders.

In summary, the rigor of capital cost planning focuses the attention from the level of the individual principal investigator managing and accountable for running his or her laboratory and clinic to the NIH Director on the NIH shared scientific mission; identifies realistic vulnerabilities and opportunities in the built environment to support the science; recognizes the financial constraints and capabilities facing the NIH center or program; and from the national perspective, enhances the financial viability and stability of the IRP by confronting the likely challenge of never having sufficient capital to meet all of its needs.[13]

---

[10] D. Wheeland, "Sustainment and Improvement Strategy," presentation to the HHS Capital Investment Review Board, July 2016.

[11] D. Wheeland, "Modernization of NIH Facilities and Infrastructure," presentation to the HHS Secretary's Budget Council Meeting, September 23, 2016.

[12] NIH Office of Research Facilities, "NIH Condition Index, Sustainment and Improvement Funding Needs Plan," via e-mail, June 14, 2018.

[13] Government Finance Officers Association, "Best Practices," https://www.gfoa.org/best-practices, accessed August 30, 2018.

Capital and Cost Planning for the Research Enterprise

NIH, Stanford University (see Box 6.2), and the USDA ARS (see Box 6.3) utilize multiple and different levels of detail for capital project cost models at different stages of the capital planning process. As noted earlier, capital cost models developed for specific capital projects serve as the only realistic foundation for short-, mid-, and long-range institutional capital plan prioritization. The preliminary and later planning phase capital cost projections are key to successfully supporting the effectiveness of the NIH Capital Plan, whether as part of a request seeking authorizing legislation at the federal level of the Operating Divisions with HHS, or by an individual project manager within the ORF, who is managing the project to ensure that the project's scope, schedule, and total cost identified earlier is balanced with the authorized appropriation. By supporting the capital plan, the NIH mission is served. Simply accelerating a response to the needs for new or improved space and facilities by the staff of the ORF, which may be out of balance with the available capital resources and the constantly evolving strategic scientific priorities, will only accelerate the degradation and limit the IRP's strategic scientific missions.

BOX 6.2
Stanford University's Capital Planning

Stanford University is an example of a large-scale research enterprise with a capital plan similar to the ambition of the most recent NIH Intramural Research Program capital budget request. A private academic research institution and, of course, not subject to federal compliance as an Department of Health and Human Services Operating Division, Stanford University's "Capital Plan" utilizes a 3-year plan that identifies only those projects that have been approved, including funding sources identified (or nearly so), and includes three major categories for fiscal year (FY) 2017 to FY 2020: "Projects in Design and Construction" ($2.9 billion, see Table 6.2.1); "Forecasted Construction Projects" ($3.5 billion); and "Infrastructure and Other [Housing]" ($4.3 billion). Operating budget impacts for institutional operations and maintenance expenditures are included along with projected cash flow expenditures (often beyond the 3-year plan) integrating institutional operating and capital financial management as required due to funds sources requirements and related financial commitments by schools or departments or philanthropic organizations or individuals. Stanford's longer-term capital plan is a more flexible forecast and evolves based on financial feasibility or shifts in institutional priority.

SOURCE: Stanford University, 2017a, "Capital Plan and Capital Budget," Chapter 4 in *Stanford University Budget Plan 2017/18*, https://bondholder-information.stanford.edu/pdf/BudgetBookFY18.pdf.

Box continues with Table 6.2.1

TABLE 6.2.1 Stanford University 2017/18-2019/20 Capital Plan (in millions of dollars)

	Fiscal Year Project Schedule	Estimated Project Cost	Capital Budget 2017/2018	Current Funds	In Hand or Pledged	To Be Raised	Service Center/ Auxiliary Debt	Academic Debt	Other	Resources to be Identified[a]	Debt Service	Operations & Maintenance
Escondido Village Graduate Residences												
—*Residence Building*	2016-2021	1,009.2	159.7	209.2	150.0	50.0	600.0				31.2	9.7
—*Underground Parking Garages*	2016-2021	82.5	11.5	82.5								2.4
Stanford Redwood City Phase 1	2015-2019	568.8	329.4	25.0				543.8			32.1	21.2
Neuro/ChEM-H Research Complex	2015-2019	257.0	119.2	109.5	102.0	23.0		22.5			1.3	6.6
Center for Academic Medicine 1 (CAM 1)												
—*Building*	2017-2020	166.0	77.4					31.3	134.7		1.8	2.2
—*Underground Parking (854 spaces)*	2017-2020	56.9	26.5	51.9				5.0			0.3	1.8
BioMedical Innovations Building 1 and Tunnel (BMI 1)	2017-2019	210.0	104.0	20.0	102.5	47.5		40.0			2.4	2.4
University Terrace Faculty Homes	2013-2018	176.5	45.0				162.0		14.5			
Anne T. and Robert M. Bass Biology Research Building												
—*Bass Biology Building*	2014-2018	125.6	56.5	58.1	49.9	6.9		10.7			0.6	4.2
—*Connective Elements*	2014-2018	4.7	2.1	0.2	4.5							
—*Central Loading Dock and Stauffer III Demolition*	2015-2018	21.9	0.3	1.9				20.0			1.2	(0.2)
Frost Amphitheater Improvements	2015-2018	33.5	19.9		33.5							0.6
Public Safety Building	2017-2019	31.5	12.4	31.5								0.8
Encina Complex Upgrades	2016-2019	25.8	6.6	14.5	11.3							
Athletic Academic Advising and Rowing Building	2017-2018	25.0	16.7	4.2	18.1	2.7						0.4
Denning House	2016-2019	23.1	15.0		23.1							0.5
Durand Renovation—Phase 4	2017-2018	17.4	10.3	17.4								
Environmental Health and Safety Facility Expansion	2017-2019	16.5	12.6		2.0			14.5			0.9	0.3
Children’s Center of Stanford Community	2017-2019	11.5	7.2	11.5								0.3
Schwab Residential Center Renovations	2017-2018	11.3	3.8	11.3								
District Work Centers	2017-2019	8.5	5.0					8.5			0.5	0.2
Stanford Oak Garden Children’s Center	2017-2020	7.5	4.8	7.5								0.2
Subtotal—Projects in Design and Construction		2,890.7	1,045.9	656.2	496.9	30.1	762.0	696.3	149.2	—	72.3	53.6

[a] Anticipated funding for this category is through a combination of school, department, and university reserves, and other sources.

BOX 6.3
USDA Agricultural Research Service Capital Planning

The U.S. Department of Agriculture's (USDA's) principal intramural scientific research agency, the Agricultural Research Service (ARS), published its "capital investments strategy" in 2012 at the request of the USDA Secretary in response to Senate and House Reports in fiscal year (FY) 2011 and FY 2012. The Senate Report (111-221) directed the Secretary "to evaluate the agency's capital asset requirements" and House Report (112-101) "directs ARS to establish a long term, multi-year plan to guide capital asset construction decisions for new agricultural research buildings and facilities consistent with program missions, goals, and requirements."[1] The study suggests guidance for future USDA Administration capital budget requests in the short, mid-, and long term, but the primary focus was on identifying appropriate criteria for capital investments in new facilities and infrastructure as well as investments in repair, consolidation, and closure of existing capital assets to avoid unnecessary future investments when funds might not be available and scientific research could be negatively impacted.

Due to the inherent location-specific mission of agricultural scientific endeavor, the study identifies project-specific capital investment recommendations for both the renovation/repair of existing capital assets identified in each of the five ARS Geographic Areas Capital Project & Repair Plans, but also development of new USDA ARS research facilities. The most current USDA ARS capital budget summary of the USDA ARS's prioritization and cost estimates for new building and capital renewal or recapitalization of existing buildings and infrastructure by geographic area was approximately $640 million in FY 2020 costs.[2]

Table 5 of that publication, "Recommended Out-Year Capital Investments for Modernizing or Replacing ARS Research Facilities" (see Table 6.3.1) was included in the congressional-requested study and resulted in funding for FY 2017 appropriation per the following:

> For ARS Buildings and Facilities, the agreement provides an appropriation of $99,600,000 for priorities identified in the USDA ARS Capital Investment Strategy, April 2012, including not less than $5,100,000 for planning and design purposes for the next highest priorities identified in the USDA Capital Investment Strategy.[3]

[1] U.S. Department of Agriculture, 2012, *The USDA Agricultural Research Service Capital Investment Strategy*, Washington, D.C.
[2] S. Liu, 2018, "The Agricultural Research Service (ARS) Capital Investment Strategies," presentation to the committee, August 8.
[3] U.S. Department of Agriculture, 2017, "Division A–Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriations Act, 2019," Appropriations Explanation Statement, https://nifa.usda.gov/sites/default/files/resource/2017-Appr-Expln-Stmnt-DivisionA-NIFALanguage.pdf, p. 7.

Box continues with Table 6.3.1

TABLE 6.3.1 Recommended Out-Year Capital Investments for Modernizing or Replacing Agricultural Research Service (ARS) Research Facilities

Priority Group	Location	Name	Estimated Cost ($ millions)	Group Total ($ millions)
1	Athens, GA	Southeast Poultry Research Laboratory	145	145
2	Frederick, MD[a]	Fort Detrick Foreign Disease-Weed Science Research	70	
	Beltsville, MD	B-307A (Animal Science, Human Nutrition, and Bee Research)	33	103
3	Tucson, AZ	Southwest Watershed Research Laboratory	10.5	
	Houston, TX	Children's Research Nutrition Research Center	25	
	Clay Center, NE	U.S. Meat Animal Research Center	55	
	Ames, IA	National Lab for Agriculture and the Environment	12	102.5
4	Salinas, CA	U.S. Agricultural Research Station	82	
	Kerrville, TX	U.S. Livestock Insect Research Laboratory	45	127
5	Temple, TX	Grassland, Soil, and Water Research Laboratory	15	
	Madison, WI	U.S. Dairy Forage Research Center (Prairie du Sac)	46.2	
	Tifton, GA	Southeast Watershed Research Laboratory	27.5	
	University Park, PA	U.S. Pasture Laboratory	15.5	104.2
6	Gainesville, FL	Center for Medical, Agricultural, and Veterinary Entomology	45	
	Geneva, NY[a]	Grape Genetics/Genomics Laboratory	37.8	
	Corvallis, OR	National Clonal Germplasm Repository	8.5	91.3
7	Beltsville, MD	Utility infrastructure upgrade and B-007, B-006, and B-002 modernization (crop, food, and natural resources research)	77	
	Oxford, MS	U.S. Sedimentation Laboratory	20.5	97.5
8	Pullman, WA[a]	Crop and Land Management Research	62	
	Beltsville, MD	National Agricultural Library	32.5	94.5
9	Athens, GA	Richard B. Russell Research Center	140	140

[a] ARS-owned replacement of cooperator facility.

FINDINGS AND RECOMMENDATIONS

Finding: The NIH-Wide Strategic Plan 2016-2020 sets forward the overall objectives of NIH research activities. However, as noted in the April 2016 Clinical Center Working Group Report to the Advisory

Committee to the Director, there was "inadequate attention to capacity and prioritization: There is little scientific prioritization across ICs, and this becomes particularly problematic in the case of shared resources." The risks inherent in leading-edge clinical research and hospital operations generally differ from those associated with biomedical research. The NIH-Wide Strategic Plan also does not consider the current, mid-term, or long-term implications of the proposed research with respect to its capital facility assets, including all buildings and infrastructure.

Finding: The NIH 2013 Bethesda Campus Master Plan explicitly references the NIH-Wide Strategic Plan (albeit from an earlier year), and prioritizes renewing aging physical facilities and reducing leased space. This Master Plan, however, has not been updated (as far as it has been presented to the committee) to reflect (1) changes in research strategic goals; (2) changes in research processes, personnel, and methods that affect space use and utilization; (3) progress to date on improved, renovated, or new capital facility assets (including buildings and infrastructure); and (4) changes in partnering opportunities and challenges.

Finding: The NIH currently has a detailed process for capital investment planning, as evidenced in the NIH Design Requirements Manual for new or renovated biomedical research and animal care facilities. While the HHS Form 300—FPAA requires evidence of projected institutional operating budget impacts associated with the proposed capital investment requested, the data appear to be incomplete in so far as they are limited to traditional maintenance and utility operating budget impacts.

Finding: Current Bethesda Campus cost planning utilizes a diverse and inconsistent range of capital cost model data and templates, with apparently regular modification of an informal cost model "template" by individual project officers or others.

Finding: The Bethesda Campus project and cost planning data do not appear to be evaluated by a peer expert panel. As noted by the April 2016 Clinical Center Working Group Report to the Advisory Committee to the Director, NIH, there was "no independent entity to verify that engineering controls for high-risk facilities meet appropriate regulations or standards prior to or after construction." The committee was unable to identify evidence that formal or informal third-party peer review of NIH ORF preplanning PORs or total project capital cost models have been adopted.

Finding: Current capital investment planning does include a consideration of current maintenance backlog items, which appear to be input when maintenance staff familiar with Bethesda Campus buildings recognize critical needs. In addition, NIH employs an external contractor on a regular cycle to assess facility conditions and flag systems at the end of their useful life; key buildings undergo a comprehensive conditions audit on a regular and consistent schedule. However, these maintenance backlogs and condition assessments are not prioritized to maintain critical NIH mission activities.

Finding: Currently, NIH-peer state-of-the-art medical research organizations establish management processes and procedures that integrate the organization's Strategic Plan with a Master Plan for facilities, infrastructure, and space needs across multiple schools, departments, divisions, or laboratories into one comprehensive financial annual planning and forecasting process. This integrated Strategic and Master Plan offers the opportunity to create a transparent and rigorous criteria for prioritization of financial operating and capital resource allocation.

Finding: Both the NIH-Wide Strategic (Research) Plan and the campus Master Plan, discussed above, emphasize the importance of enhancing interactions and collaboration among IRP research personnel and partners through shared space and facilities and the need for flexible and adaptable facilities to accommodate these collaborations and rapidly changing research program needs.

Recommendation 6.1: NIH should integrate its research strategic plan with its capital facility asset management plans, with explicit prioritization aimed at relating the long-term research strategy to the long-term campus Master Plan. This integration should include a rigorous and detailed 10-year plan for reduction of its Backlog of Maintenance and Repair that is embedded within the institution's major capital improvement plan (currently the Buildings and Facilities/Nonrecurring Expenses Fund-funded 5-year plan). These plans should undergo annual review, redevelopment as needed based on review, and adoption at the highest levels of NIH.

Recommendation 6.2: NIH should establish a formal external interdisciplinary peer review panel to provide ongoing review of NIH capital assets, the annual project plan, the 5-year plan, the master plan, and the integrated research strategic plan and master plan, including enhancing interactions and collaboration among Intramural Research Program research personnel and partners.

Recommendation 6.3: NIH should establish processes and a system that ensure third-party, expert peer review of all adopted Office of Research Facilities preplanning programs of requirements and total project capital cost models.

7

The Future of Capital Planning for the NIH Bethesda Campus

INTEGRATING STRATEGIC RESEARCH PROGRAM AND STRATEGIC CAPITAL FACILITIES PLANS

Background

In the preceding chapters of this report, the committee has described how and why the National Institutes of Health (NIH) Intramural Research Program (IRP) may be vulnerable and its mission at risk unless there is a timely reassessment and readjustment of the agency's capital planning processes and associated funding. At the same time, the committee acknowledges and commends the work of the Office of Research Facilities Division of Technical Resources (DTR) team on the Bethesda Campus. Its capital infrastructure collaborative planning processes can serve as an excellent starting point, in part, to support the integration of the IRP scientific program objectives balanced by similarly required robust planning—planning by the DTR leadership, which has proven to be innovative, rigorous, and financially sustainable.[1]

Specific findings in the Clinical Center Working Group Report to the Advisory Committee to the Director (NIH ACD, 2016) regarding the condition of NIH facilities highlight the critical importance of the built environment to the ability of NIH to achieve its mission. Inefficient facilities management and deteriorating building and site infrastructure systems have been demonstrated to undermine mission performance and workforce productivity within both private and public sector research enterprises.

By providing an objective and accurate assessment of an institution's built environment, as well as its developmental potential, rigorous facilities capital planning can serve as a critical component of effective biomedical research and healthcare strategic planning (Manevich, 1985). Wasteful expenditures are avoidable through application of the most fundamental and key steps of strategic capital facilities planning, ensuring that a comprehensive evaluation of critical program and capital facilities is completed and impacts

---

[1] See National Institutes of Health, "HHS Assistant Secretary Bardis Visits, Tours," *NIH Record*, Vol. LXIX, No. 17, August 25, 2017, https://nihrecord.nih.gov/newsletters/2017/08_25_2017/seen.

to the strategic program plan are identified. Last, while the needs for major capital facilities investments are often clear to facilities engineers and program leaders, institutional leaders must continually reprioritize formal allocation of capital investments in the institutional capital plan to enhance emergent as well as the highest ongoing existing program priorities (Glagola, 2002).

Existing Practices of Federal Agency Research Enterprises

To fulfill the committee's charge to "review comparable available facility condition methodologies and metrics of other federal agencies at an overall portfolio level," four federal agencies with scientific missions presented their capital asset management practices to the committee. These were (1) the Naval Research Laboratory (NRL); (2) the National Institute of Standards and Technology (NIST); (3) the National Aeronautics and Space Administration (NASA); and (4) the Agricultural Research Service. Similar to NIH's IRP, each of these entities has in-house research professionals, specialized research equipment and test facilities, and research-focused capital assets. In addition, the committee reviewed a recent report by the Institute for Defense Analysis on the capital planning, prioritization, and management at 10 research laboratories that conduct U.S. national security research (see the section "Institute for Defense Analyses Benchmarking Analysis of Federal Security Laboratories" in Chapter 7). The committee also briefly reviewed a recent report from the Government Accountability Office on best practices for federal real property asset management (GAO, 2018), which reviewed practices at six federal agencies (see the section "GAO Report on Best Practices for Federal Real Property Asset Management" in Chapter 7).

Naval Research Laboratory

NRL was established in 1923, to "Conduct a broadly based multidisciplinary program of scientific research and advanced technology development directed toward maritime applications of new and improved materials, techniques, equipment, systems and ocean, atmospheric, and space sciences and related technologies."[2] NRL is administratively housed under the Navy's Chief of Naval Research, and conducts approximately $1.3 billion of research annually. The majority (60 percent) of the research funds come from the Department of the Navy. Approximately one-third of NRL's funding comes from research contracts with other Department of Defense (DoD) offices, and a small amount (about 7 percent) comes from other U.S. government or industry contracts.

The main NRL research facility is located in Washington, D.C. (NRL-DC), and consists of 22 buildings on 880 acres. NRL also operates facilities for flight support (Patuxent River, Maryland), corrosion (Key West, Florida), oceanography and marine geosciences (Stennis Space Center, Mississippi), and marine meteorology (Monterey, California). Major shared facilities across NRL include (1) global satellite operations; (2) scientific research library; (3) Institute for Nanoscience (Class 100 clean room, 5,000 square feet); (4) Laboratory for Autonomous Systems Research; and (5) VXS-1 (scientific research squadron). The NRL-DC buildings date from the 1930s to 1950s.

NRL employs approximately 2,400 personnel (see Table 7.1).

The NRL capital asset management program is supported through a 2 percent fee on all research contracts. New capital expenditures for equipment or specialized facilities is covered either through direct expense to the research contract, covered under the NRL-wide general and administrative (G&A) account, or through a specific military construction (MILCON) appropriation (although MILCON funds are rare; NRL just received one approval after not having received one for 12 years).

[2] B. Danly, "Naval Research Laboratory Overview," presentation to the committee, August 8, 2018.

TABLE 7.1 Naval Research Laboratory Personnel

Personnel	FY 2017
Science and engineering professionals	1,630
Specialists and analysts	407
S&E technicians	118
Administrative support	240
Total	2,395

NOTE: FY, fiscal year; S&E, science and engineering.
SOURCE: B. Danly, "Naval Research Laboratory Overview," presentation to the committee, August 8, 2018.

The NRL Corporate Facilities Investment Plan explicitly analyzes the link between mission, research, and facilities, and is aligned with the Naval Warfare Center, and in collaboration with the DoD Defense Advanced Research Projects Agency. Recent NRL capital asset initiatives include an "Innovation Space" for new collaborative research efforts, as well as extensive sharing of specialized equipment and laboratory space. The Naval Research Advisory Committee panel,[3] which is composed of external experts, reviews NRL progress, challenges, and opportunities, and reports to the NRL Director of Research. The Head of Business Operations, who has responsibility over all finances as well as facilities, reports to the Director of Research.

National Institute of Standards and Technology

NIST was established in 1901 as the Bureau of Standards. Its mission is "To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life."[4] NIST is the only broad-based research laboratory in the Department of Commerce, and in FY 2018 conducted approximately $685 million in Scientific and Technical Research and Services (STRS), and an additional $152 million in Industrial Technology Services (ITS).[5] Each lab within NIST can charge a fee for the use of its specialized equipment and facilities by other government agencies and industry; those revenues stay within that lab's finances.

The NIST main campus is in Gaithersburg, Maryland, and consists of 579 acres with 61 buildings (3.6 million gross square feet [GSF]). NIST operates three additional sites: (1) Boulder, Colorado, with 206 acres and 30 buildings (896,000 GSF); (2) Fort Collins, Colorado, with 390 acres and 5 buildings (19,000 GSF); and (3) Kauai, Hawaii, on the Barking Sands Pacific Missile Range Facility, which covers 31 acres and has one building (6,000 GSF). The majority of the NIST-Gaithersburg facilities date from the 1960s, with several major additions during the early 2000s. The majority of the Boulder facilities date from the 1950s.

NIST employs approximately 3,300 personnel (full-time, part-time, and student employees) and approximately 5,550 full-time and part-time associates (NIST, 2017a). The majority of those employees (2,742) are employed at the Gaithersburg campus. NIST reported approximately 440 employees working at its facilities in Boulder, Colorado.

---

[3] See the U.S. Navy Naval Research Advisory Committee website at https://www.nrac.navy.mil/.

[4] National Institute of Standards and Technology, "NIST Mission, Vision, Core Competencies, and Core Values," updated January 26, 2017, https://www.nist.gov/about-nist/our-organization/mission-vision-values.

[5] National Institute of Standards and Technology, "Budget Tables," updated December 21, 2018, https://www.nist.gov/fy-2019-presidential-budget-request-summary/budget-tables.

TABLE 7.2 NIST Fiscal Year 2018 Budget for Capital Asset Management

Source	Budget ($ millions)
IS Funding (Facilities Services)	25.3
Utilities (IS Funds)	33.3
CRF/SCMMR Projects	295.0[a]
SCMMR (Non-Projects)	24.3
Program Management, Safety, Sustainability	3.9
Facilities Operations and Maintenance	15.0
Design and Construction Staffing	5.4
Total	377.9

[a] Actual CRF/SCMMR FY 2018 budget is $319 million.
NOTE: CRF, Construction of Research Facilities; FY, fiscal year; IS, Institutional Support; SCMMR, Safety, Capacity, Maintenance, and Major Repairs.
SOURCE: R.C. “Skip” Vaughn; NIST, “Capital Planning at the National Institute of Standards and Technology,” presentation to the committee, August 9, 2018.

At NIST, all nonstaffing costs against STRS (i.e., lab programs) and Industrial Technology Services (ITS—extramural programs) are taxed at a rate of 29 percent. Nonstaffing costs associated with the budget line items, Construction of Research Facilities/Safety and Capacity, Maintenance, and Major Repairs (CRF/SCMMR), are charged at a rate of 1.5 percent. All such funds are used for what might be deemed support costs: human resources, budget, information technology (to a degree), acquisitions, safety, general administration, utilities, and facilities (i.e., operations, services, and grounds maintenance).

The FY 2018 Budget for NIST capital asset management was $378 million (see Table 7.2).

NIST is currently assessing the Facility Master Plan across the Gaithersburg and Boulder campuses with an eye toward reducing extensive lab customization, shifting toward IT-based research, and encouraging significant collaboration across NIST labs. The prioritization within the Master Plan is based on a Condition Index (CI), and a 5-year projection of capital needs that will identify and renew or develop additional critical major infrastructure systems and capital assets. Major new appropriations currently provide an opportunity to renew and expand capital assets on NIST campuses. Management priorities include expansion planning to implement an increase in capital expenditure from $40-50 million per year to $250 million per year. The periodic reviews of the strategic value of NIST research activities by external expert panels do not usually concern capital assets. There does not appear to be shared laboratory space or extensive sharing of specialized equipment or testing facilities. The chief facilities management officer reports to the associate director of management resources, who reports to the NIST Director and Under Secretary of Commerce for Standards and Technology.

National Aeronautics and Space Administration

NASA was established in 1958 to develop peaceful applications of space science. NASA’s total budget for FY 2017 was $19.6 billion, which included $361 million for construction and environment (Davis, 2017). NASA also receives lease payments, which equaled $2.3 billion in FY 2017 (13 percent of NASA’s spending authority), primarily through commercial leasing of facilities (NASA OIG, 2018). For example, Google paid NASA an initial base rent of $3.7 million per year to lease 42 acres of unimproved land in

NASA Research Park,[6] and leased NASA's Moffet Airfield for 60 years, for a total of $1.6 billion in rent over the life of the agreement (Kastrenakes, 2014).

NASA has nine research centers: (1) Ames Research Center; (2) Armstrong Flight Research Center; (3) John H. Glenn Research Center at Lewis Field; (4) Goddard Space Flight Center; (5) Lyndon B. Johnson Space Center; (6) John F. Kennedy Space Center; (7) Langley Research Center; (8) George C. Marshall Space Flight Center; and (9) John C. Stennis Space Center. The Jet Propulsion Laboratory is a federally funded research and development center managed by the NASA Management Office. NASA also has seven installations with component facilities. NASA manages over 3,000 buildings and facilities (47 million square feet), including 695 labs.

NASA currently employs 17,002 personnel, including 455 students, and 86 term or other nonpermanent personnel.[7] It employs 11,058 science and engineering professionals, including 182 students, and 23 term or other nonpermanent personnel.

The NASA capital asset management program has its own line-item appropriation.

NASA is currently developing a Master Plan across all locations and directorates to assess the current NASA mission need for facilities, particularly compared with the current plethora of existing (and outmoded) facilities. Recent NASA capital asset priorities include significant increases in new collaborative research efforts, as well as extensive sharing of specialized equipment and laboratory space.

Other key priorities include reducing unscheduled maintenance (currently at 30 percent of annual expenditures) by 1 percent per year, using a new reliability-based maintenance management system, and reducing operating expenses using strategic portfolio management. Each NASA lab has external expert review panels that assess both the research and the facilities of that lab, and across NASA. The Office of Strategic Infrastructure reports to the Associate Administrator of Mission Support, who reports to the NASA Administrator.

Agricultural Research Service

The ARS of the U.S. Department of Agriculture was founded in 1953 with a mission to

> Conduct research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to:
>
> - Ensure high-quality, safe food, and other agricultural products;
> - Assess the nutritional needs of Americans;
> - Sustain a competitive agricultural economy;
> - Enhance the natural resource base and the environment;
> - Provide economic opportunities for rural citizens, communities, and society as a whole; and
> - Provide the infrastructure necessary to create and maintain a diversified workplace.[8]

ARS operates over 95 research facilities in five regions across the United States: (1) Pacific West; (2) Plains; (3) Midwest; (4) Northeast; and (5) Southeast. The ARS conducted approximately $1.5 billion in research in FY 2017, a large majority (92 percent) of which was funded by the Department of Agriculture,

---

[6] John Shonder, Oak Ridge National Research Laboratory, NASA Facilities Engineering and Real Property Conference, 2011, https://fred.hq.nasa.gov/Capital assets/Docs/ConferenceNashville2011/Tuesday/Shonder-AltFinEULPPA.pdf.

[7] NASA, "Workforce Information Cubes for NASA," https://wicn.nssc.nasa.gov/wicn_cubes.html.

[8] See the U.S. Department of Agriculture's (USDA's) Agricultural Research Service website at https://www.ars.usda.gov/about-ars/.

3 percent by other federal departments, and approximately 3 percent by nonfederal funders, including in collaboration with land grant universities.[9]

ARS-owned capital assets include approximately 388,000 acres of land and 3,095 buildings (approximately 15 million GSF). Approximately 40 percent of the buildings (including laboratories) are over 50 years old. ARS also leases over 400,000 GSF, and occupies over 600,000 GSF under memorandums of understanding with states and other federal agencies.[10]

In FY 2017, ARS employed 5,522 personnel, including both field and Washington, D.C., personnel.[11]

Within the ARS, projects pay 4 percent of their research funds for facility repairs and maintenance.[12]

The capital asset management for ARS consists of an agency-wide Capital Asset Management Committee, which includes research administrators, the budget director, and facility directors and research directors for each region. In addition, each region has a capital asset management committee, as does each location. An external expert review panel meets three times each year to review research progress and facilities based on the following criteria: (1) relevancy; (2) impact; (3) capacity (such as human resources and infrastructure); (4) innovation; (5) quality; and (6) technology transfer.

The annual assessment of ARS capital management projects requires formal alignment with the research assessment and utilizes a current building condition index to compile an annual, mid-range, and long-range capital projects prioritization report reviewed and approved by the ARS senior administrative leadership team. The ARS uses the U.S. Army Corps of Engineers and one of the common institutional commercial software building conditions program to track and assess capital assets.

Ongoing ARS capital asset priorities are reported to be effective due to the nature of the ARS extensive collaborative research efforts with land grant universities and agricultural industry researchers, often sharing laboratory space and specialized plant biosciences equipment and facilities. The associate administrator for research and operations reports directly to the ARS budget director.

Summary of Comparable Portfolio Capital Asset Management at Federal Research Agencies

All four federal agencies that presented their capital asset management practices to the committee have instituted external expert panels to assess research missions, and three of the four agencies use external panels to assess the alignment of the agency's mission with capital facility assets management and planning (see Table 7.3). Three of the four agencies have also established programs to enhance shared facilities, including specialty equipment and research space, and have designated funding to encourage collaboration across organizational units. Two of the agencies focus collaboration support toward organization-wide themes, and one focuses on regionally based intergroup themes. All four federal agencies have explicit mechanisms to support capital facility assets by all of its organizational units, ranging from a proportion of all research funds to a space usage charge (e.g., "rent"). In addition, three of the agencies charge external organizations (public or private organizations) fees for usage of specialty facilities or space. The reporting structures for facilities management and planning differ across the four agencies, with two agencies reporting that facilities management reports within the research mission structure, and two agencies reporting within the organization's finance administrative hierarchy.

---

[9] A further 2 percent arises from miscellaneous contributions; see USDA, "2018 President's Budget. Agricultural Research Service," https://www.obpa.usda.gov/18arsexnotes2018.pdf.

[10] S. Liu, USDA Agricultural Research Service, "ARS Capital Planning at the USDA Agricultural Research Service," presentation to the committee, August 9, 2018.

[11] See USDA, "2018 President's Budget. Agricultural Research Service," https://www.obpa.usda.gov/18arsexnotes2018.pdf, p. 18-7.

[12] S. Liu, USDA-ARS, communication to M. Offutt, National Academies of Sciences, Engineering, and Medicine, December 21, 2018.

TABLE 7.3 Comparable Portfolio Capital Asset Management at Four Federal Research Agencies

	DoD NRL	DOC NIST	NASA	USDA ARS
Mission context	Global competencies and capabilities	National need (commerce)	Global/extraterrestrial	Regional, national, and international
Mission and facilities	External expert panels assess mission and facilities	External panels assess mission by research area	External expert panels assess research and facilities	• Stakeholder input • External experts panels assess research
Flexible space/shared facilities	• Shared specialty equipment • Shared space • Shared funding	No/little shared	• Moving toward shared specialty equipment • Shared space	• Shared with land grant universities • Extramural and intramural co-located
Research themes	• Organization-wide themes • Intergroup themes	- Standards-focused	• Organization-wide themes • Intergroup themes	• Regional intergroup themes • Response to international threat/risk
Support of core capital assets and initiatives	• Innovation space • 2% of all revenue to director's fund	• 29% indirect cost recovery • Test facility rental (external researchers, industry)	• "Rent" fee • Test and launch facility rental (industry)	• "Rent" fee • Facilities or land rental (land grant universities)
Facility management and governance	FM reports to Research Director	FM director reports to Associate Director of Management	FM reports to Associate Administrator of Mission Support	FM Associate Administrator reports to Budget Director

NOTE: ARS, Agricultural Research Service; DOC, Department of Commerce; DoD, Department of Defense; FM, Facilities Management; NIST, National Institute of Standards and Technology; NASA, National Aeronautics and Space Administration; NRL, Naval Research Laboratory; USDA, U.S. Department of Agriculture.

Institute for Defense Analyses Benchmarking Analysis of Federal Security Laboratories

In 2013, the Institute for Defense Analyses (IDA) reviewed the capital facilities planning, prioritization, and management practices at 10 research laboratories that conduct national security research. The IDA report examined the planning processes, prioritization criteria, stakeholder involvement and communication, and data and metrics used to guide investment in capital facility assets (Howieson et al., 2013). The focus of the analysis is the facilities and infrastructure required to meet the national and homeland security missions of DoD, Department of Energy (DOE), and Department of Homeland Security (DHS). The 10 laboratories included in this assessment are listed in Table 7.4.

TABLE 7.4 Federal Laboratories in Institute for Defense Analyses Study

Agency	Laboratory	Type
DoD	Air Force Research Laboratory (AFRL)	GOGO
DoD	Army Medical Research Institute for Infectious Diseases (AMRID)	GOGO
DoD	Army Research Laboratory (ARL)	GOGO
DoD	Naval Research Laboratory (NRL)	GOGO
DoD	Massachusetts Institute of Technology Lincoln Laboratory (MIT-LL)	FFRDC
DOE	Brookhaven National Laboratory (BNL)	FFRDC
DOE	Los Alamos National Laboratory (LANL)	FFRDC
DOE	Sandia National Laboratories (Sandia)	FFRDC
DHS	National Biodefense Analysis and Countermeasures Center (NBACC)	FFRDC
DoD	Johns Hopkins University Applied Physics Laboratory (JHU-APL)	UARC

NOTE: DoD, Department of Defense; DOE, Department of Energy; DHS, Department of Homeland Security; FFRDC, federally funded research and development center; GOGO, government operated, government owned; UARC, university-affiliated research center.
SOURCE: Howieson et al. (2013), p. 3.

The analysis found significant challenges at these federal research laboratories in securing the needed investment in critical facilities, equipment, and infrastructure (F&I). The report concluded that a major challenge for capital investment is the lack of organization and agency leadership and commitment for championing capital requirements during annual budget development and final recommendations, in part, to limited integration between institutional capital plans and institutional strategic research goals, objectives, and vision.

During the planning process, these laboratories often lacked "an integrated agency plan to address long-term F&I needs across the agency and the national security enterprise" (Howieson et al., 2013, p. iv). In addition, the agency and department often develop prioritization criteria and metrics that do not include F&I impacts on mission capabilities, and the F&I investment prioritization criteria are often not linked to the agency-level priorities. The study found that, in part, the planning and prioritization challenges were often due to the lack of communication among stakeholders for the federal security laboratories, and particularly the missing link of the dependence of mission capabilities on F&I capital assets. This challenge of establishing the mission-F&I dependence is complicated by the need for detailed data, metrics, and analysis, which is often expensive and time-consuming to collect and consistently update.

Each of the laboratories cited in the IDA report has implemented strategies to address these challenges. For the purposes of this report on the NIH Bethesda Campus, certain strategies are heighted below.

IDA Observations on Peer-Reviewed Space, Equipment, and Infrastructure Performance and Highest Value Capital Investments to Meet Scientific Goals and Objectives

The IDA report (Howieson et al., 2013) cites multiple examples where these research enterprises have established panels of external and internal subject matter experts to identify and measure key performance indicators that will successfully integrate F&I investments and agency mission capabilities. These panels have facilitated more open and effective communications among multiple stakeholder groups and particularly scientists, financial leaders, and facilities architects and engineers. The panels appear to have been successful in the development and assessment of key capital investment prioritization metrics, which were expected to create more efficient capital investment results for the research mission. Key observations from the report include the following:

- "In November 2011, the LANL [Los Alamos National Laboratory] Director announced the creation of the Laboratory Integrated Stewardship Council, which comprises the Associate Director of Capital Projects and other program leadership. The council will approve projects over $100,000 in an effort to better manage budget constraints that will impact future activities at the laboratory" (Howieson et al., 2013, p. 22).
- "The DHS uses the cyclic Planning, Programming, Budgeting, and Execution (PPBE) process to identify mission gaps and guide investment decisions in the annual budget and Resource Allocation Plan. The planning component of the PPBE outlines the DHS's long-term strategic direction assuming no budgetary constraints, while the programming, budgeting, and execution components focus on budgetary resource allocations to fund, deploy, and support programs over the next 5 years. As part of the PPBE process, the DHS (2008) established a streamlined acquisition lifecycle framework in 2008 composed of four phases:
    - *Need:* The directorates and offices review a preliminary Mission Needs Statement to identify whether items in the statement are unique needs or are being addressed by other DHS activities. If the needs are approved as unique, the directorate submits a Mission Needs Statement to the DHS and the Joint Requirements Council.
    - *Analyze/Select:* The DHS identifies alternatives to fulfill the mission need defined in the Mission Needs Statement and selects an option based on cost, schedule, and risk.
    - *Obtain:* The DHS further refines logistics and funding through testing and evaluation to ensure the capability can operate as expected when deployed.
    - *Produce/Deploy/Support:* The DHS reviews plans for production readiness, staffing, and funding and approves deployment." (Howieson et al., 2013, p. 22-23)
- The DHS also uses various supporting boards and working groups to aid F&I investment decisions. The Acquisition Review Board reviews and approves Level 1 and 2 projects at each phase of the acquisition life-cycle framework. Moreover, the Program Review Board reviews and makes recommendations on projects to the DHS Secretary; the Joint Requirements Council assesses the project's alignment with strategic requirements; and the Capital asset Review Board is responsible for managing the DHS capital portfolio. Groups external to the agency may also be consulted for input into F&I plans. For example, Office of National Laboratories (ONL) staff coordinated with federal intelligence agencies and other potential customers when planning the National Biodefense Analysis and Countermeasures Center (NBACC)." (Howieson et al., 2013, p. 23)
- "The DoD's Defense Medical Facilities MILCON Capital Investment Decision Model and the National Nuclear Security Administration's (NNSA) Construction Working Group are two examples where this occurs. These decision-making models are effective ways to communicate and link F&I needs to current and future missions across the agency. Both the Capital Investment Decision Model and Construction Working Group facilitate agreement on the top F&I needs across the DoD and the NNSA enterprises, respectively." (Howieson et al, 2013, p. 31)
- The NNSA Construction Working Group also serves as a way for laboratories and leadership to better understand the cross-competencies and unique capabilities across the NNSA laboratories. NNSA staff is developing a similar model to coordinate deactivation and decommissioning activities. The NNSA conducted two teleconferences and invited all stakeholders to participate in 4- to 8-hour sessions in which all proposed projects were reviewed and feedback on each one was provided. This process resulted in fewer complaints the following year about involvement and the prioritization of projects." (Howieson et al, 2013, p. 31)

IDA Observations on Identification of Alternative Research Enterprise Revenue to Support Increased Capital Resources to Meet Facilities and Investment (F&I) Requirements

The report cites several examples of research laboratories that generate F&I operations and capital investment funding through a centrally managed "rent" or "tax" applied to the research enterprise expenditures. In general, the university-affiliated research center laboratories generate central fund sources through a percentage fee applied to all research enterprise expenditures.

IDA Observations on Enhanced Outcomes and Leverage of Existing Capital Assets in Research Collaboration and Engagement Among Multiple Research Enterprises

Several laboratories reviewed in the report explicitly collaborate with other agencies and organizations to increase capital asset utilization and advance agency mission objectives. Specific examples include the following:

- DHS funded the National Infrastructure Simulation and Analysis Center at Sandia, which is staffed by personnel from DHS, Sandia, and LANL.
- The DoD laboratories regularly conduct research across the military departments.
- The DOE laboratories conduct research and share equipment with other DOE programs.
- Several laboratories shared facilities with nonfederal research partners, such as through Cooperative Research and Development Agreements.
- "In July 2010, the secretaries from the DoD, DOE, and DHS and the Director of National Intelligence developed the 'Governance Charter for an Interagency Council on the Strategic Capability of DOE National Laboratories as National Security Capital Assets.' The interagency council serves to review the science and technology capabilities across the DOE laboratories for supporting government-wide national security missions. The interagency council also presents a formal mechanism for agencies to support research needs across the federal agencies." (Howieson et al., pp. 46-47)
- "In November 2011, the Navy headquarters office established the Naval Laboratory and Centers Coordinating Group (NLCCG), a coordinating body created to promote communication among leadership in the Navy's laboratories and research centers. The NLCCG covers various management and operations dimensions, including facilities, workforce, and technical research capabilities. The Navy headquarters staff expressed their hopes that the NLCCG would also serve as a mechanism to advocate and better communicate a consistent message of F&I needs to the Navy and other DoD agency staff as well as other R&D capital asset stakeholders." (Howieson et al., p. 47)

IDA Observations on Developing Improved Capital Facilities Investment Planning Processes to Meet Research Mission Objectives

The report cited several examples at different laboratories of processes to establish the link between F&I investments and meeting mission objectives.

- "DOE-SC's Mission Readiness Peer Review sends F&I personnel from DOE-SC laboratories to assess the F&I process of other DOE-SC laboratories. Instead of attempting to compare laboratories' data, the Mission Readiness Peer Review assesses the mission readiness process itself and whether it is aligned with the laboratory's mission objectives. Laboratories involved in the peer review team are asked to evaluate whether the process is comparable to one that would be produced by their own laboratory." (Howieson et al., 2013, p. 63)

- "NBACC and JHU-APL select comparison laboratories based on their research area to improve the accuracy of the benchmark." (Howieson et al., 2013, p. 64)

GAO Report on Best Practices for Federal Real Property Asset Management

The Government Accountability Office (GAO, 2018) was asked to review the best practices of federal real property asset management, particularly the applicability of International Organization for Standardization (ISO) 55000 standard on asset management. GAO reviewed six federal agencies as case studies: (1) General Services Administration; (2) NASA; (3) National Park Service; (4) U.S. Army Corps of Engineers; (5) U.S. Coast Guard; and (6) U.S. Forest Service.

The GAO report identified "six key characteristics of an effective asset management framework: (1) establishing formal policies and plans, (2) maximizing an asset portfolio's value, (3) maintaining leadership support, (4) using quality data, (5) promoting a collaborative organizational culture, and (6) evaluating and improving asset management practices" (p. 10). The GAO report also found that:

- "Five of the agencies linked their asset management goals and objectives to their agency mission and strategic objectives in their asset management plans." (GAO, 2018, p. 16)
- "Each of the six agencies we reviewed has documentation describing a process for prioritizing asset investments … based on specific criteria, such as the risks an asset poses to agency operations, asset condition, project cost, and project impact." (GAO, 2018, p. 16)

The GAO report recommends that the Office of Management and Budget (OMB) should update its guidance to federal agencies to improve federal real property asset management "to develop a comprehensive approach to asset management that incorporates strategic planning, capital planning, and operations, and maintaining leadership support, promoting a collaborative organizational culture, and evaluating and improving asset management practices." (GAO, 2018, p. i).

CAPITAL ASSET PORTFOLIO PERFORMANCE-BASED CAPITAL PLANNING DECISION MAKING

As noted in the previous section, NIH is one of multiple scientific government research agencies engaged in strategically aligning facilities and their real estate portfolio to achieve future organizational goals, while contending with decreasing budgets and rising facility operating costs, in combination with responding to technological and socioeconomic drivers and federally mandated compliance requirements. (Further discussion may be found in Appendix I.)

As the role of facilities and infrastructure in support of government and private sector day-to-day operations is made more apparent, their efficiency, reliability, cost effectiveness, and sustainability will become even more important. Facilities typically account for almost 25 percent of the value of an organization's total capital assets and are either the second or third highest operating cost after people (salaries and benefits) or after people and information technologies. Nevertheless, many facilities are deteriorating due to aging and inadequate maintenance and repair. This is particularly noteworthy because their poor performance due to their deteriorated operating condition hinders federal agency personnel from performing and achieving their mission. An acknowledgement of facility costs, how facility performance influences business operations, and the impact of the built environment on workforce health and safety have prompted organizations to take a more strategic approach to facilities management, viewing them as capital assets that enable the production and delivery of goods and services (NRC, 2008).

There is growing recognition within the national and global research enterprise of the critical need for capital investment strategies that move beyond focusing on simply meeting research program capital needs through investments in capital asset creations without proactive acknowledgement and identification of the long-term total cost of ownership, operations, and maintenance, as well as rehabilitation, replacement, and retirement. Facilities capital asset management has been defined by the National Research Council (NRC, 2004) "as a systematic process for maintaining, upgrading, and operating physical capital assets cost effectively." Effective facilities capital asset management combines engineering principles with sound business practices and economic theory and provides tools to facilitate a more organized and logical approach to decision making. Federal agencies began capital asset management implementation actions in response to Executive Order 13327, issued February 4, 2004, which required all federal entities to take a more corporate approach to managing real property capital assets by developing capital asset management plans, establishing appropriate performance measures, and gaining an understanding of life cycle costs of the inventory (IWR, 2013). Publicly available information on federal agencies shows that some of them have successfully adopted capital asset management and activity management programs. This has allowed them to reduce their real property portfolio costs and dramatically improved their facility and infrastructure effectiveness and efficiency. For example, the 2004 GAO *Water Infrastructure* report (GAO, 2004) described how utilities that have started using comprehensive capital asset management reporting are able to make more informed decisions about how best to manage the capital assets. In particular, utilities are using the information they collect to allocate their maintenance resources more effectively and make better decisions about whether to rehabilitate or replace aging capital assets. The effective management of capital assets over the life of their operation and use requires a total cost of ownership financial approach that considers the interrelationships between operations and maintenance costs on one hand and facility capital investments on the other, to help minimize total life cycle costs and maximize capital asset availability and utilization (NRC, 2008).

For further discussion, see Appendix I, "Capital Asset Portfolio Performance-Based Capital Planning Decision Making."

In conclusion, the committee believes that integrating current best practices of capital facility capital asset management into NIH's short-, mid-, and long-term financial planning processes would provide an accountable framework that would much more effectively enhance the necessary alignment of the built environment portfolio performance with NIH's diverse research program objectives.

FINDINGS AND RECOMMENDATIONS

Findings

Finding: The deteriorated condition of the facilities on the Bethesda Campus is an indication that appropriate funding has not been made available to support necessary maintenance and repairs. Other federal government organizations have developed an F&I analysis process that has demanded a new or adjusted "rent" or "tax" process to better align common funds for common use facilities.

Finding: The reporting structures for facilities management and planning differ across federal agencies. In general, capital facilities planning leadership and management tends to be led by the research scientist community, but some federal agencies collaborate with the capital facilities financial and technical staff (engineers, architects, and planners) as peers to align agency mission with F&I investment and prioritization.

Finding: Several federal agencies interviewed by the committee, and having scientific missions themselves, have capital facilities planning governance structures that place research and the facilities that support them on an equal footing. These agencies further have capital or real estate strategies.

These strategies and functions are developed and executed by an associate director (or equivalent), reporting to the agency director.

Finding: Due to the accelerating competition for capital resources in both the private and public sectors of the national and global research enterprise, the role of capital facilities financial planning is recognized as a critical component requiring subject matter expertise within central administrative leadership to support institutional financial sustainability. In addition, more comprehensive capital facilities plan and capital projects reviews are required to achieve a more highly integrated capital and scientific program decision making model that is more quantitative, objective, and subject to rigorous peer review external to NIH or HHS.

Finding: The U.S. GAO emphasizes the need for federal agencies "to develop a comprehensive approach to asset management that incorporates strategic planning, capital planning, and operations, and maintaining leadership support, promoting a collaborative organizational culture, and evaluating and improving asset management practices." (GAO, 2018, p. i)

Recommended Strategies to Accommodate Short-, Mid-, and Long-Range Capital Planning Process Improvements at NIH

Recommendation 7.1: NIH should study the non-NIH federal research programs described in this report, among others, and incorporate or adopt, where appropriate, functionally similar assessment, prioritization, and funding strategies for the purpose of better meeting facilities and infrastructure investment needs.

Recommendation 7.2: NIH should implement a capital facilities planning governance structure, functionally similar to that utilized by other scientific agencies noted in this report, aimed at facilitating an integrated, transparent, and inclusive capital asset planning decision making process. This governance structure should facilitate tracking the agency's progress toward achieving its strategic and programmatic objectives.

Recommendation 7.3: NIH should convene an annual capital facilities planning workshop or similar forum with other federal agencies and academic research institutions for the purpose of assessing NIH capital asset management program processes and identifying improvements, including the ongoing development of a capital financial resource sustainability plan. The proceedings of this workshop and any recommendations should be distributed to the institutes and centers and central administrative leaders, among others, and be used to inform Intramural Research Program budget development. There should be broad participation in the workshop, including by principal investigators, junior faculty, and research laboratory staff; capital and operating budget staff; information technology leaders; capital planning staff; campus infrastructure operations staff and maintenance leaders; and representatives from other federal agencies and academic research institutions.

Recommendation 7.4: To verify the presence of subject-matter expertise within its core administrative leadership, NIH should review and consider whether its organizational structure ensures that its Bethesda Campus scientific research and capital assets management strategies and plans are aligned. In doing so, NIH should consider how other federal agencies with research missions have accomplished this end by assigning a senior organizational leader with such responsibilities and empowering that person with commensurate authority.

8

The Evolving Global Biomedical Research Environment and Its Implications for NIH Capital Assets

BACKGROUND AND CONTEXT

Based on its deliberations over the course of 18 months, the committee believes that the Intramural Research Program (IRP) on the Bethesda Campus is a vital and essential part of the National Institutes of Health (NIH). In this vein, the committee feels that NIH needs to give more attention to the evolving and increasingly competitive global biomedical research environment that is driving the need for a different type of research-built environment. Without serious consideration of and attention to these dynamics (refer also to Chapter 2), the committee believes that the IRP is likely to be increasingly disadvantaged when competing against other national and international biomedical research centers.

The committee identified multiple issues that were not within its investigational charge per se, but that materially bear on the management of the Bethesda campus's capital assets. The committee feels that it would be remiss if it did not note these issues and call for their further assessment. These issues relate to (1) NIH's organizational structure and culture; (2) organizational and structural barriers to team science; and (3) data access and management issues.

The committee was not able to delve into these issues in great depth, but it did spend significant time evaluating and discussing them through the lens of their implications for space and facilities use on the Bethesda Campus, especially in the long term. The committee concluded that the issues called out above deserve to be investigated more thoroughly, with an eye toward their implications for both the NIH scientific enterprise and its capital assets management.

ORGANIZATIONAL STRUCTURE AND FUNDING

As mentioned in Chapter 3, NIH has a unique organizational structure that has developed less by forethought than by happenstance as its health and national security missions have evolved over the years. This disparate funding and political support across the ICs means that some institutes are essentially functionally independent organizations from NIH as a whole. For example, with the exception of some patient care and clinical research at the Clinical Center, the National Cancer Institute performs most of its intramural research at locations other than the Bethesda Campus (e.g., at the Frederick National Laboratory located 50 miles northwest of Washington, D.C., and at the Shady Grove campus).

In FY 2017, NIH's appropriated funds totaled $33 billion, including $5.9 billion for the National Cancer Institute (18 percent of NIH's budget), $4.7 billion for the National Institute of Allergy and Infectious Diseases (14 percent of NIH's budget), and $3 billion for the National Heart, Lung and Blood Institute (9 percent of NIH's budget) (see Figure 8.1).

The confluence of widely disparate IC budgets, NIH's intrinsically fractured and siloed organizational structure, and a culture led by individuals recognized for their deep expertise within narrowly defined areas of science has led to a palpable organizational bias to use funds to support scientific research over integration of strategic plans and promotion of shared facility assets that support team science.

Since 2003, NIH funding has not kept pace with inflation, and the agency has lost 22 percent of its research purchasing power. Likewise, funding for the Buildings and Facilities account has remained relatively static over the last 20 years, not allowing the organization to keep up with inflation or aggregate funding for larger capital expenditures (see the section "Funding for Capital Projects," in Chapter 4). And while difficult to measure, there is a linkage between the level of funding for facilities and the NIH intramural programs, the latter charged in the NIH-Wide Strategic Plan (NIH OD, 2015) with the following:

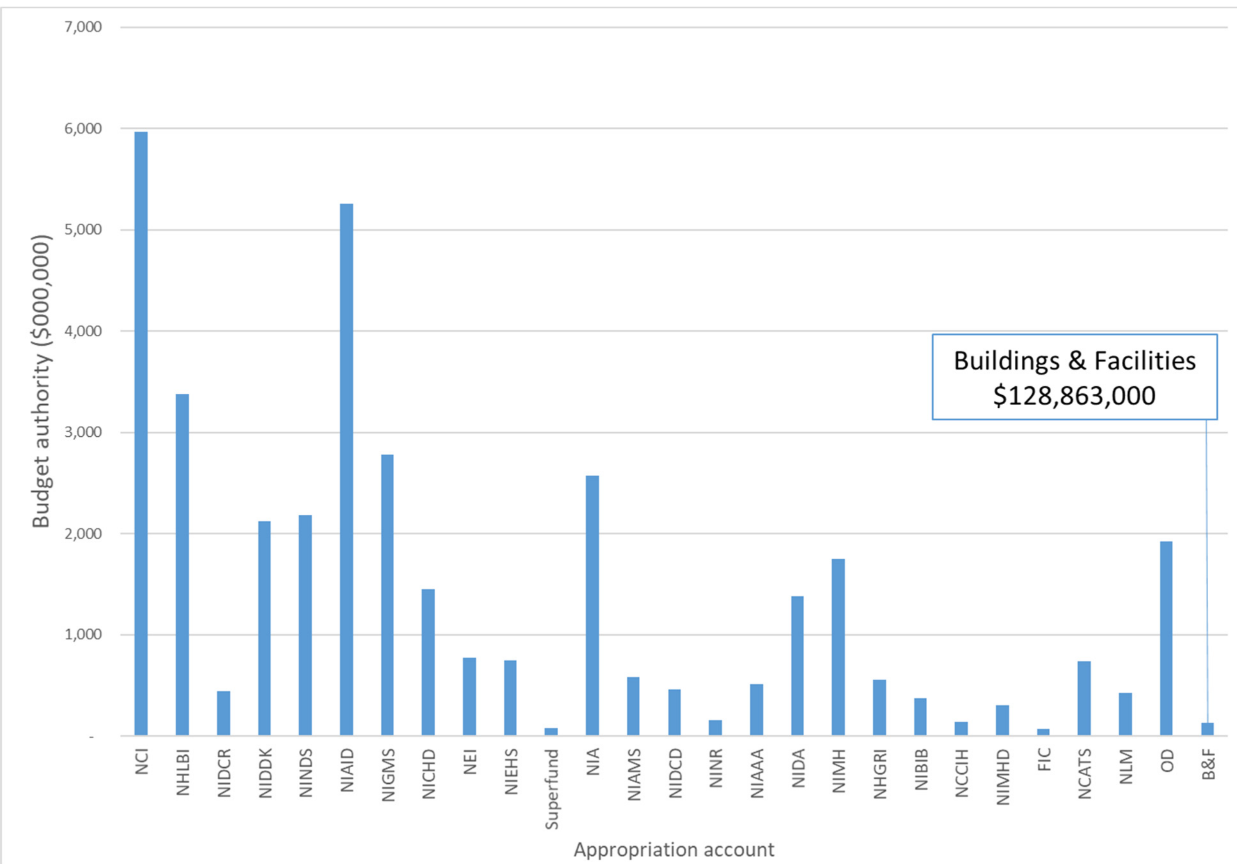


FIGURE 8.1 NIH budget authority by appropriation account for FY 2018 (in $ millions) NOTE: 24 of the 27 ICs have a line-item appropriation, while three of them—Clinical Center, Center for Information Technology, and Center for Scientific Review—do not. NOTE: Acronyms can be found in Appendix K. SOURCE: Neil K. Shapiro, NIH, "The NIH Budget," presentation to the committee on May 16, 2018.

- To prevent dire impact to individual and community's health;
- To retain a world-class biomedical workforce; and
- To remain competitive in the global business environment.

The Bethesda Campus's challenge is not a uniquely NIH challenge. Many of the same forces affect biomedical research facilities across the nation and globe. Today's biomedical research organizations are large, complex, and highly sophisticated enterprises, although they are not always viewed as such and enabled with appropriate infrastructures for planning and management.

NIH's challenges for setting priorities, developing sound administrative capital asset strategies, and managing according to them is compounded by it being a federal government agency that must contend with the vagaries and intrinsic challenges of government funding. State research universities often also struggle with this reality, in comparison to private universities, but federal government agencies must contend with even more public attention and scrutiny.

As noted earlier, each NIH institute or center receives congressional appropriations, albeit often from different House and Senate committees. These congressional entities, who often represent powerful health advocacy groups, often define major capital asset investments, such as new buildings, but have not generally recognized overall NIH-wide and campus needs.

The above-noted funding dynamics lead to widely different amounts of funding for the 27 ICs and the overall IRP. This presents a significant challenge to enterprise-wide coordination and planning. Each of the units comprising NIH has its own staff members that relate to strategic and facilities planning, with the individual ICs enjoying different perceptions and levels of support.

MULTIDISCIPLINARY TEAM SCIENCE

The concept of "team science," defined as scientific collaboration by more than one individual in an interdependent fashion, has evolved because of the increasing need to bring experts from multiple disciplines together to address complex problems (NRC, 2015). The impact of funded scientific collaborations across organizations and institutional boundaries nationally and internationally is reflected by the increased number of multi-authored publications in peer-reviewed journals (Llewellyn et al., 2018). In 2010, the National Cancer Institute published "Collaboration and Team Science: A Field Guide" to help guide the institutional organizational and cultural change needed to support the change from single investigator-led projects to multidisciplinary team-led projects that emphasize collaboration across disciplinary dedicated departments and ICs (Bennett et al., 2018).

In 2015, the National Academies published a report requested by the National Science Foundation to provide guidance on how best to address the challenges of conducting research collaboratively (NRC, 2015). The report reviewed the emerging evidence from the new interdisciplinary scientific research field of "science of team science" (SciTS) on the effectiveness and challenges of team science.

This emerging field of empirical knowledge can guide funding agencies, policy makers, scientists, and organizational leaders on how to effectively support team science and a culture of collaboration (Hall et al., 2018; NRC, 2015). Of the seven key challenges for teams that were addressed in the study, geographical dispersion was identified as the main problem, and hence, the need for different facility and built-environment designs. The ability to co-locate research teams in an adaptable, technologically advanced contemporary biomedical work environment is essential to facilitate collaboration and support innovation. High-performance computing and a state-of-the-art information technology and communications infrastructure are necessary to support "big data" analytics and the connectivity requirements of local, national, and international team collaboration. Building an infrastructure to support team-based science is essential to stay viable in a global biomedical research environment that is intensely competing for top talent.

Having flexible and adaptable contemporary biomedical research space is essential to accommodate the current and future needs of multidisciplinary research teams. Team-based science requires a high degree of social interaction, and the work environment needs to support various models of collaboration and interaction. For example, desire for adjacency of "dry lab"-based computational scientist and "wet lab"-based researchers to support purposeful interaction and generation of new ideas requires buildings with access to a high-performance computational infrastructure and state-of-the-art laboratory and core facilities. The trend toward the development of interdisciplinary scientific neighborhoods made up of multiple open laboratories, shared lab support areas, office space, formal and informal meeting spaces, along with open shared collaboration spaces, breaks down the traditional alignment of space according to academic or research line disciplines. Furthermore, the growth of the innovation economy and the development of innovation districts and spaces to support institutional collaborations, incubators, and start-up spaces, create ecosystems that are changing the way people work and collaborate (Wagner and Watch, 2017). Biomedical research organizations focused on attracting the millennial generation of scientists will need to incorporate innovation into their building design and campus programming. With few exceptions, the current built environment at NIH is not well designed to support these new models of team-based and transdisciplinary science.

Most biomedical research organizations in the United States engage in enterprise-wide coordination and planning. The NIH Long-Term Intramural Research Program (LT-IRP) Planning Working Group (NIH ACD, 2014) recommends that such activities be strengthened in one of its recommendations, as follows:

> 3. Encourage interdisciplinary and team science and promote more synergistic intramural and intramural-extramural collaborations through continued development and evaluation of different research structures.
>
> a. Evaluate the Porter Neuroscience Research Center approach to integrated science.
> b. Develop a mechanism to respond to emergent health crises.
> c. Modify mechanisms to allow for more expansive IRP-extramural interactions.
> d. Host annual scientific meetings at NIH. (p. 2)

An example noted in the above recommendation from the LT-IRP with respect to buildings and facilities is the John Edward Porter Neuroscience Research Center (PNRC)—one of the few examples of a built environment to support transdisciplinary research on the NIH campus. To quote an NIH website:

> More than a decade ago, neuroscience leaders at the National Institutes of Health (NIH) foresaw the need to catalyze collaboration across the many diverse subfields of brain research. Their vision gave rise to the concept of a new type of research facility, one that would unite neuroscience research across the NIH. At the time, neuroscientists in NIH's intramural research program were located in at least eight different buildings. Congress embraced this bold vision, and, in 2000, provided funds to create a national neuroscience research center on NIH's Bethesda, MD, campus that would bear the name of a longtime champion for biomedical research, Congressman John Edward Porter. Every aspect of this 500,000 square foot, state-of-the-art complex speaks to the ingenuity and wisdom of its distinguished namesake—from the interactive labs and shared resource spaces to the innovative features that make it one of the world's most energy-efficient life science facilities. The John Edward Porter Neuroscience Research Center [PNRC] is the home for 85 groups, encompassing more than 800 scientists. Within these walls, through wide-ranging studies exploring everything from genetics to behavior, these creative minds will seek to unlock the mysteries of the nervous system in health and disease. Through their efforts, this center will serve as a premier institution for brain research, as well as forge a new model for the collaborative conduct of biomedical research across the country and around the globe.[1]

This vision for collaborative research seems to be experiencing several challenges in current operations. For example, the PNRC is already oversubscribed, often yielding cramped research space. Areas designed

---

[1] National Institutes of Health (NIH), "The John Edward Porter Neuroscience Research Center," https://www.nih.gov/about-nih/john-edward-porter-neuroscience-research-center, accessed February 7, 2019.

to facilitate casual interaction among researchers can be so small that the spaces feel constrictive, while circulation spaces, including massive hallways, can be underutilized. Current maintenance and repair issues, such as water leaks into new laboratory spaces, require researchers to hang plastic sheeting around expensive equipment to protect the equipment and allow research to continue.

The committee believes that NIH needs to achieve better coordination of planning for a built research environment that will result in a world-class infrastructure that includes facilities and state-of-the art technology that will enable interdisciplinary team-based research in flexible and adaptable facilities capable of supporting present needs and of accommodating future research demands. This will require breaking down traditional organizational silos, along with new approaches and cultural changes that drive collaboration and integration.

The challenges described here are not unique to the NIH campus. For more than 10 years, major academic institutions such as Stanford University and Northwestern University have made major investments in replacing old infrastructure and in building research environments that support team science and encourage interdisciplinary studies to quickly move biomedical research into clinical practice.[2] Boston University's newest research building was designed to foster collaboration between researchers, postdoctoral fellows, and graduate students via "communication staircases" connecting floors and labs. The former "corner office" prime real estate is shared collaboration space that is available to everyone.[3] In 2016, the Crick Institute, Europe's largest biomedical research building, was established through a collaboration among six founding partners: the Medical Research Council, Cancer Research UK, Wellcome, UCL, Imperial College London, and King's College London. The facility brings together 1,500 investigators and staff working collaboratively across disciplines and makes state-of-the-art science technology platforms available to researchers across the United Kingdom.[4] The Paul Allen Institute's new 270,000-square-foot research building in Seattle, Washington, "is designed to process huge amounts of complex research data requiring information technology efficiencies and team-centered facility design. It implements an innovative floor plan to integrate lab space, office space, meeting space, natural lighting, air flow, and, most importantly, movement of people." According to the institute's director of operations, the goal was "to take the basic research model and scale it up to a more team-oriented environment" (Woofenden, 2018).

Recommendation 8.1: NIH should explicitly prioritize the initiatives specified within the NIH-wide Strategic (Research) Plan and the 2013 Bethesda Campus Master Plan (or its successor), which emphasize the importance of enhancing interactions and collaboration among Intramural Research Program (IRP) research personnel and partners through shared space and facilities, and the need for flexible and adaptable facilities to accommodate such collaborations and rapidly changing research program needs. This should apply to existing facilities as well as new facilities, and through further enhancement of key strategic shared core assets such as Biowulf and the Clinical Center.

---

[2] See Stanford University (2017b) and the Northwestern University website for the Louis A. Simpson and Kimberly K. Querrey Biomedical Research Center at https://www.feinberg.northwestern.edu/sites/simpson-querrey, accessed January 14, 2019.

[3] *BU Today*, 2017, "Designing Science: Newest BU Research Center Is Built for Collaboration," updated September 14, http://www.bu.edu/today/2017/kilachand-center-for-integrated-life-sciences-and-engineering-science-building-design/.

[4] Crick Institute, "The Francis Crick Institute," https://www.crick.ac.uk, accessed January 14, 2019.

DATA DRIVEN SCIENCE

The development and advancement of "big data" science are materially changing the approaches to biomedical research, requiring new methods that span scientific disciplines and require cross-cutting integration of basic biology and human health sciences. To continue to be a global leader in biomedical research, NIH will need the financial and human resources to leverage advancements in big data and turn them into discoveries that improve health. One very promising area is the current activity with cloud computing for the entire NIH enterprise. Work with Google Cloud and Amazon Web Services through the Data Sciences Strategy is moving along, and plans are to use the cloud for data calculations as well as data storage. The committee believes that similar efforts are needed in the area of utilizing augmented and artificial intelligence across all of the intramural programs.

Building 12, which houses the data center, is slated for replacement in the Master Plan and currently has not been funded while awaiting completion of FY 2018-2022 priorities. The building is at risk due to inadequate utility capacity, including an estimate showing inadequate generator power capacity by 2020, and chilled water-cooling capacity in 2017. While there is a project to increase chilled water capacity by July 2019, it is contingent on new funding.

The recently enacted Twenty-First Century Cures Act (Public Law 114-255) includes an initiative at NIH known as the "All of Us" program.[5] The goal is to collect comprehensive personal health information (PHI) in a secure database that is accessible for research. However, this very commendable effort is challenged by current federal policy regarding access to PHI for research purposes. Such policies do not bode well for "precision medicine" research. Indeed, it is easier for Facebook or Google to access PHI than it is for health researchers to do so through either informed consent or Institutional Review Boards. This issue is not unique to NIH, and major progress using big data may require changes in data access policies.

CONCLUSION

The dynamics discussed above and in Chapters 2 and 3 with respect to the national biomedical and health research enterprise have material implications for the size and scale of NIH's physical plant, operations, and scholarly pursuits. It was beyond the committee's charge to delve into NIH's scientific and clinical programs per se, or into the forces driving the evolving and increasingly competitive global biomedical research environment, but in so far as biomedical and clinical research models substantially drive what is needed in the way of capital assets, the committee encourages the NIH leadership to more closely link planning for scientific inquiries with planning for its built environment. Further, in light of the multiple factors that are driving the evolution of biomedical research and the resultant changes in how biomedical research is conducted, the committee strongly encourages NIH to engage in a rigorous and ongoing strategic assessment of its investigative portfolio and how such relates to its capital asset needs.

[5] See the National Institutes of Health All of Us Research Program website at https://allofus.nih.gov/.

9

Recommendations

NECESSARY SHORT-TERM ACTIONS

Recommendation 4.1: The currently identified $1.3 billion in the Backlog of Maintenance and Repair (BMAR) should be funded in two tranches. First, fund the entire long-term infrastructure improvements totaling approximately $700 million over a specific time period (e.g., 5 years) so that a comprehensive plan can be undertaken to support the ongoing research activities and begin preparation and support for any future Master Plan improvements. (The full title is "2013 Comprehensive Master Plan—Bethesda Campus.") Second, the remaining $600 million needs to be considered for each building in light of its future as defined in the approved Master Plan.

Recommendation 5.2: NIH should utilize the changes in the Building and Facilities prioritization model to complete an analysis of projects to modify or replace Building 12, the Building 14/28 complex, and various active or planned projects to renovate or replace portions of Building 10 occupied by the Clinical Center. If the analysis supports a high priority for these projects, then NIH should continue with efforts to move forward as quickly as possible with these projects.

REVISE EXPENDITURE PLANNING PROCESSES AND PRACTICES

Recommendation 4.2: The Buildings and Facilities account, or other account, should have an annual dedicated investment amount—determined by considering the amount of Backlog of Maintenance and Repair (BMAR), building condition index, and historical levels of spending—for reduction or elimination of BMAR that can be used only for this purpose.

Recommendation 4.3: NIH should adopt and implement a Deferred Maintenance and Repair program focused on building and utility system condition data that will minimize or eliminate

specific failures that are disruptive to mission accomplishment and to reduce Backlog of Maintenance and Repair while attaining the building Condition Index (CI) target stated in the Master Plan. The methods that the committee recommends for capital planning prioritization—that is, incorporating CI and mission dependency—can be adapted for this purpose.

IMPROVE CAPITAL PLANNING TOOLS AND METHODS

Recommendation 5.1: NIH should revise its Building and Facilities (B&F) prioritization model so that a significant portion of the 1,000-point scoring system (no less than one-third of the total points) includes the Condition Index and Mission Dependency Index as objective parameters. Using this revised model, NIH should reassess all current projects in the 5-year B&F plan. The balance of the $1.3 billion of funding (i.e., $600 million) should be prioritized based on this assessment. This assessment could also be used to determine the annual required funding set aside.

Recommendation 7.1: NIH should study the non-NIH federal research programs described in this report, among others, and incorporate or adopt, where appropriate, functionally similar assessment, prioritization, and funding strategies for the purpose of better meeting facilities and infrastructure investment needs.

TREAT THE CAMPUS AND ITS ACTIVITIES AS AN INTERRELATED AND INTEGRATED SYSTEM

Recommendation 6.1: NIH should integrate its research strategic plan with its capital facility asset management plans, with explicit prioritization aimed at relating the long-term research strategy to the long-term campus Master Plan. This integration should include a rigorous and detailed 10-year plan for reduction of its Backlog of Maintenance and Repair that is embedded within the institution's major capital improvement plan (currently the Buildings and Facilities/Nonrecurring Expenses Fund-funded 5-year plan). These plans should undergo annual review, redevelopment as needed based on review, and adoption at the highest levels of NIH.

SOLICIT INPUT FROM EXPERTS EXTERNAL TO NIH

Recommendation 5.3: NIH should seek out the federal agencies referenced in this report, along with other similar agencies, to determine if there are best practices that it can utilize. NIH should consider regular (e.g., quarterly) engagements with these agencies to review its Capital Asset Management Program, as well as how the engagement of key individuals from the institutes and centers (at all levels of the organization who are impacted by the program) and the private sector could enhance the success of NIH projects.

Recommendation 6.2: NIH should establish a formal external interdisciplinary peer review panel to provide ongoing review of NIH capital assets, the annual project plan, the 5-year plan, the master plan, and the integrated research strategic plan and master plan, including enhancing interactions and collaboration among Intramural Research Program research personnel and partners.

Recommendation 6.3: NIH should establish processes and a system that ensure third-party, expert peer review of all adopted Office of Research Facilities preplanning programs of requirements and total project capital cost models.

Recommendation 7.3: NIH should convene an annual capital facilities planning workshop or similar forum with other federal agencies and academic research institutions for the purpose of assessing NIH capital asset management program processes and identifying improvements, including the ongoing development of a capital financial resource sustainability plan. The proceedings of this workshop and any recommendations should be distributed to the institutes and centers and central administrative leaders, among others, and be used to inform Intramural Research Program budget development. There should be broad participation in the workshop, including by principal investigators, junior faculty, and research laboratory staff; capital and operating budget staff; information technology leaders; capital planning staff; campus infrastructure operations staff and maintenance leaders; and representatives from other federal agencies and academic research institutions.

REVISE GOVERNANCE

Recommendation 7.2: NIH should implement a capital facilities planning governance structure, functionally similar to that utilized by other scientific agencies noted in this report, aimed at facilitating an integrated, transparent, and inclusive capital asset planning decision making process. This governance structure should facilitate tracking the agency's progress toward achieving its strategic and programmatic objectives.

Recommendation 7.4: To verify the presence of subject-matter expertise within its core administrative leadership, NIH should review and consider whether its organizational structure ensures that its Bethesda Campus scientific research and capital assets management strategies and plans are aligned. In doing so, NIH should consider how other federal agencies with research missions have accomplished this end by assigning a senior organizational leader with such responsibilities and empowering that person with commensurate authority.

Recommendation 8.1: NIH should explicitly prioritize the initiatives specified within the NIH-wide Strategic (Research) Plan and the 2013 Bethesda Campus Master Plan (or its successor), which emphasize the importance of enhancing interactions and collaboration among Intramural Research Program research personnel and partners through shared space and facilities, and the need for flexible and adaptable facilities to accommodate such collaborations and rapidly changing research program needs. This should apply to existing facilities as well as new facilities, and through further enhancement of key strategic shared core assets such as Biowulf and the Clinical Center.

References

AACR (American Association for Cancer Research). 2014. NIH Clinical Center open to collaboration. *Cancer Discovery* 4(7):752. doi: 10.1158/2159-8290.CD-NB2014-065.

ACRP (Association of Clinical Research Professionals). 2018. "5 Clinical Research Trends at ACRP 2018." June 11. https://www.acrpnet.org/2018/06/11/5-clinical-research-trends-emerge-at-acrp-2018.

Bennett, L.M., H. Gadlin, and C. Marchand. 2018. *Collaboration and Team Science: A Field Guide* (ed. National Cancer Institute). U.S. Department of Health and Human Services, National Institutes of Health, Washington, D.C.

Boddie, C., M. Watson, and T.K. Sell. 2016. Federal funding for health security in FY2017. *Health Security* 14(5):284-304. doi: 10.1089/hs.2016.0063.

Chakma, J., G.H. Sun, J.D. Steinberg, S.M. Sammut, and R. Jagsi. 2014. Asia's ascent—Global trends in biomedical R&D expenditures. *New England Journal of Medicine* 370(1):3-6.

Chang, M., and F.B. Grieder. 2016. Sharing core facilities and research resources—An investment in accelerating scientific discoveries. *Journal of Biomolecular Techniques* 27(1):2-3. doi: 10.7171/jbt.16-2701-004.

Chang, M.C., F.B. Grieder, and J. Anderson. 2015. U.S. National Institutes of Health core consolidation—investing in greater efficiency. *Journal of Biomolecular Techniques* 26:1-3.

Conte, M.L., J. Liu, S. Schnell, and M. B. Omary. 2017. Globalization and changing trends of biomedical research output. *JCI Insight* 2(12):e95206. doi: 10.1172/jci.insight.95206.

Davis, J. 2017. "NASA's 2018 Budget Request Is Here, and We Broke Down the Details." Planetary Society. May 23. http://www.planetary.org/blogs/jason-davis/2017/20170523-nasa-full-2018-budget-request.html.

DHS (Department of Homeland Security). 2008. *Acquisition Instruction/Guidebook 102-01-001*. Washington, D.C.

DOI (U.S. Department of the Interior). 2005. *Capital Asset Priority Index Guidance*. https://www.doi.gov/sites/doi.gov/files/migrated/pam/programs/capital asset_management/upload/APIGuidance092105.pdf.

Ehrlich, E. 2018. "NIH's Role in Sustaining the U.S. Economy: 2018 Update Authored by Dr. Everett Ehrlich." United for Medical Research. http://www.unitedformedicalresearch.com/wp-content/uploads/2017/03/NIH-Role-in-the-Economy-FY2016.pdf.

EMRC (European Medical Research Councils). 2011. "A Stronger Biomedical Research for a Better European Future." White Paper II, 1-68. European Science Foundation. http://archives.esf.org/fileadmin/Public_documents/Publications/emrc_wpII.pdf.

ESFRI (European Strategy Forum of Research Infrastructures). 2016. *Inspiring Excellence: Research Infrastructures and the Europe 2020 Strategy*. https://ec.europa.eu/research/infrastructures/pdf/esfri/publications/esfri_inspiring_excellence.pdf.

Eulberg, D. 2008. *United States Air Force Strategic Plan*. https://afkm.wpafb.af.mil/afce.

EurekAlert! 2018. "NIAID and Children's National Partner to Advance Pediatric Clinical Research." News release. September 17. https://www.eurekalert.org/pub_releases/2018-09/nioa-nac091418.php.

Ewalt, D. 2017. "The World's Most Innovative Research Institutions—2017." *Reuters.* March 1. https://www.reuters.com/article/innovative-institutions-ranking-idUSL2N1GC1NG.

Farber, G.K., and L. Weiss. 2011. Core facilities: Maximizing the return on investment. *Science Translational Medicine* 3(95):95cm21. doi: 10.1126/scitranslmed.3002421.

Fedler, R. 2014. "Advances in Clinical Laboratory Automation." *Clinical Laboratory News.* December 1. American Association for Clinical Chemistry. https://www.aacc.org.

FEMP (Federal Energy Management Program). 2010. *Operations and Maintenance Best Practices: A Guide to Achieving Operational Efficiency.* U.S. Department of Energy, Washington, D.C.

FRPC (Federal Real Property Council). 2018. *2018 Guidance for Real Property Inventory Reporting*, Version 2. General Services Administration. August 27. https://www.gsa.gov/cdnstatic/FY2018_FRPP_DATA_DICTIONARY _v2.pdf.

GAO (U.S. General Accounting Office). 2004. *Water Infrastructure—Comprehensive Capital Asset Management Has Potential to Help Utilities Better Identify Needs and Plan Future Investments*. https://www.gao.gov/new.items/d04461.pdf.

GAO. 2015. *Federal Real Property: GSA Needs to Determine Its Progress Toward Long-term Sustainability of Its Portfolio.* GAO-15-609. Washington D.C.

GAO. 2018. *Federal Real Property Asset Management: Agencies Could Benefit from Additional Information on Leading Practices*. GAO-19-57. Washington, D.C.

Gensleron. 2015. "5 Trends That Will Shape the Future of Scientific Labs." *Building Design and Construction.* June 24. https://www.bdcnetwork.com/blog/5-trends-will-shape-future-scientific-labs.

Glagola, J.R. 2002. An introduction to strategic facilities planning. *Real Estate Issues* 27(1):13-16.

Gottesman, M.B., and A. Baxevanix. 2017. Let the cores roar: CREx will enable access to core services across the IRB. *The NIH Catalyst* 25(1). https://irp.nih.gov/catalyst/v25i1/from-the-deputy-director-for-intramural-research.

Guarino, B., E. Rauhala, and W. Wan. 2018. "China Increasingly Challenges American Dominance in Science." *Washington Post*. June 3.

Gurumeta, E. 2007. "Reliability Centered Maintenance." Paper presented at the 9th International Conference on Electrical Power Quality and Utilisation. Institute of Electrical and Electronics Engineers, Piscataway, N.J.

Hall, K.L., A.L. Vogel, G.C. Huang, K.J. Serrano, E.L. Rice, S.P. Tsakraklides, and S.M. Fiore. 2018. The science of team science: A review of the empirical evidence and research gaps on collaboration in science. *American Psychologist* 73(4):532-548. doi: 10.1037/amp0000319.

Hemmerdinger, R. 2014. *Predictive Maintenance Strategy for Building Operations: A Better Approach.* Schneider Electric, Rueil-Malmaison, France.

HHS (U.S Department of Health and Human Services). 2006. *HHS Facilities Program Manual: Volume 1.* Washington, D.C.

HHS. 2014. *National Health Security Review of the United States of America.* Washington, D.C.

HHS. 2019. *Justification of Estimates for Appropriations Committees: FY 2019, National Institutes of Health—Volume 1.* https://officeofbudget.od.nih.gov/pdfs/FY19/br/Overview.pdf.

Hirai, S., D. Krause, and G. Munson. 2004. "The Industry Use of the Facility Condition Index." Paper presented at the 2004 U.S. Department of the Interior Facilities and Capital Asset Management Conference. U.S. Department of the Interior, Washington, D.C.

Howieson, S.V., V. Peñaet, S. Shipp, K. Koopman, J. Scott, and C. Calvin. 2013. *A Study of Facilities and Infrastructure Planning, Prioritization, and Assessment at Federal Security Laboratories (Revised)*. Science and Policy Institute, Institute for Defense Analyses, Alexandria, Va.

Huang, Y., Y. Zhang, J. Youtie, A.L. Porter, and X. Wang. 2016. How does national scientific funding support emerging interdisciplinary research: A comparison study of big data research in the US and China. *PLoS One* 11(5):e0154509. doi: 10.1371/journal.pone.0154509.

IFMA (International Facility Management Association). 2007. *Exploring the Current Trends and Future Outlook for Facility Management Professionals.* Houston, Tex.

IFMA. 2011. *Facility Management Forecast—Exploring the Current Trends and Future Outlook for Facility Management.* Houston, Tex.

IWR (Institute for Water Resources). 2013. *Best Practices in Asset Management, US Army Corps of Engineers*. IWR Report 2013-R-08. U.S. Army Corps of Engineers, Alexandria, Va.

Kaiser, J. 2014. "NIH Report Warns of Looming Shortage of Physician-Scientists." *Science.* June 9. https://www.sciencemag.org/news/2014/06/nih-report-warns-looming-shortage-physician-scientists.

Kastrenakes, J. 2014. "Google Signs 60-Year Lease on NASA Airfield and Hangars." *The Verge.* November 10. https://www.theverge.com/2014/11/10/7190057/nasa-leases-moffett-airfield-to-google-60-years.

Kavanagh, S. 2007. *Financing the Future: Long-Term Financial Planning for Local Government.* Government Finance Officers Association, Chicago, Ill.

Lafrance, A. 2017. Scientists brace for a lost generation in American research. *Atlantic* 1-9.

LeMay, D., and E. Armstrong. 2009. *Federal Real Property Information Application User Manual*. https://eppley.org/resources/researchpublications/training-education/federal-real-property-information-application-user-manual-october-2009.

Lipka, M. 2016. *Aging Facilities: How Agencies Assess, Prioritize and Maintain Their Aging Facilities*. https://nsc.nasa.gov/SHLA/Content/PDFs/SHLA-Aging-Facilities-Presentation.pdf.

Llewellyn, N., D.R. Carter, L. Rollins, and E.J. Nehl. 2018. Charting the publication and citation impact of the NIH Clinical and Translational Science Awards (CTSA) program from 2006 through 2016. *Academic Medicine* 93(8):1162-1170.

Manevich, M.B. 1985. Facility planning as a component of strategic planning. *Health Care Strategy Management* 3(2):4-7.

Moses, H., III, D.M. Matheson, S. Cairns-Smith, B.P. George, C. Palisch, and E. Dorsey. 2015. The anatomy of medical research: US and international comparisons. *Journal of the American Medical Association* 313(2):174-189. doi: 10.1001/jama.2014.15939.

Motley, A. 2012. "Inner Spaces: Paradigm and Price—University of Washington." *Business Officer*. February. http://www.nacubo.org/Business_Officer_Magazine_Archives/February_2012/Inner_spaces.html.

NASA (National Aeronautics and Space Administration). 2010. *The NASA Mission Dependency Index (MDI) User Guide: Identifying the Relative Importance of Facilities.* Version 2. November. https://www.nasa.gov/offices/FRED/directives_and_requirements.

NASA OIG (Office of the Inspector General). 2018. *NASA's Management of Reimbursable Agreements*. Report No. IG-18-018. May 29. https://oig.nasa.gov/docs/IG-18-018.pdf.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2016. *Rapid Medical Countermeasure Response to Infectious Diseases: Enabling Sustainable Capabilities Through Ongoing Public- and Private-Sector Partnerships: Workshop Summary.* The National Academies Press, Washington, D.C.

NASEM. 2017. *Strengthening the Disaster Resilience of the Academic Biomedical Research: Protecting the Nation's Investment.* The National Academies Press, Washington, D.C.

NASEM. 2018a. *Advancing Disease Modeling in Animal-Based Research in Support of Precision Medicine: Proceedings of a Workshop.* The National Academies Press, Washington, D.C. https://doi.org/10.17226/25002.

NASEM. 2018b. *The Next Generation of Biomedical and Behavioral Sciences Researchers.* The National Academies Press, Washington, D.C.

NCPC (National Capital Planning Commission). 2016. *Commission Action—Project: Final 2013 NIH—Bethesda Master Plan*. file:///E:/Documents/NAS/Final%20Stretch/2013_NIH_Bethesda_Master_Plan-508tc.pdf.

Neibauer, M. 2015. "NIH to End Leases, Return Thousands of Employees to Bethesda Campus." *Washington Business Journal.* March 18. https://www.bizjournals.com/washington/breaking_ground/2015/03/nih-to-end-leases-return-thousands-of-employees-to.html.

NIH (National Institutes of Health). 2014a. "6100 Exec. Blvd. Reopens." *NIH Record* LXVI(16):3. August 1, 2014. https://nihrecord.nih.gov/pdfs/2014/08012014_Record.pdf.

NIH. 2014b. *A Decade of Discovery: The NIH Roadmap and Common Fund.* https://commonfund.nih.gov/sites/default/files/ADecadeofDiscoveryNIHRoadmapCF.pdf.

NIH. 2015a. "Bethesda Campus Master Plan Record of Decision." *Federal Register.* February 13. https://www.federalregister.gov/documents/2015/02/13/2015-02993/bethesda-campus-master-plan-record-of-decision.

NIH. 2015b. *NIH-Wide Strategic Plan Fiscal Years 2016-2020: Turning Discovery into Health*. https://www.nih.gov/sites/default/files/about-nih/strategic-plan-fy2016-2020-508.pdf.

NIH. 2016. *Clinical Center Working Group (CCWG) Report to the Advisory Committee to the Director*. Bethesda, Md.

NIH. 2017. "NIH Partners with 11 Leading Biopharmaceutical Companies to Accelerate the Development of New Cancer Immunotherapy Strategies for More Patients." News release. Modified October 12. https://www.nih.gov/news-events/news-releases/nih-partners-11-leading-biopharmaceutical-companies-accelerate-development-new-cancer-immunotherapy-strategies-more-patients.

NIH. 2018a. *Backlog Maintenance and Repair (BMAR) Reduction Plan.* January 5.

NIH. 2018b. *Report on NIH Collaborations with Other HHS Agencies for Fiscal Year 2017*. https://report.nih.gov/crs/.

NIH ACD (Advisory Committee to the Director). 2014. *Long-Term Intramural Research Program (LT-IRP) Planning Working Group Report*. December 12. https://oir.nih.gov/sites/default/files/uploads/sourcebook/documents/acd_lt-irp_wg_final_report_121514.pdf.

NIH ACD. 2015. *NIH Response and Implementation Plan: Long Term Intramural Research Program Planning Working Group Report*. Advisory Committee to the Director, June 12 meeting. https://acd.od.nih.gov/documents/reports/0612015-LT_IRP.pdf.

NIH ACD. 2016. *Reducing Risk and Promoting Patient Safety for NIH Intramural Clinical Research: The Clinical Center Working Group Report to the Advisory Committee to the Director, NIH.* Bethesda, Md.

NIH NCI (National Cancer Institute). 2018a. "Joint Design of Advanced Computing Solutions for Cancer (JDACS4C): The Right Collaboration at the Right Time to Accelerate Cancer Research." May 17. https://datascience.cancer.gov/news-events/blog/joint-design-advanced-computing-solutions-cancer-jdacs4c-right-collaboration-right.

NIH NCI (National Cancer Institute). 2018b. "NIH Management Fund, Service and Supply Fund (SSF), and GSA Rent." December 20. https://www.cancer.gov/about-nci/budget/fact-book/data/management-fund.

NIH OD (Office of the Director). 2008. *A Guide to Training and Mentoring in the Intramural Research Program at NIH*. https://oir.nih.gov/sites/default/files/uploads/sourcebook/documents/mentoring/guide-training_and_mentoring-10-08.pdf.

NIH OD. 2015. *NIH-Wide Strategic Plan, Fiscal Years 2016-2020: Turning Discovery into Health*. https://www.nih.gov/about-nih/nih-wide-strategic-plan.

NIH OIR (Office of Intramural Research). 2015. *Facilities Working Group*. Updated March 24. https://oir.nih.gov/sourcebook/committees-advisory-ddir/facilities-working-group.

NIH ORF (Office of Research Facilities). 2013. *2013 Comprehensive Master Plan—NIH Bethesda Campus*. June 14. https://www.orf.od.nih.gov/PlanningSpaceManagement/NIHMasterPlanning/Documents/2013_NIH_Bethesda_Master_Plan-508tc.pdf.

NIST (National Institute of Standards and Technology). 2017a. *Economic Contribution of Operations and Construction: FY2014–FY2016*. September. https://www.colorado.edu/business/sites/default/files/attached-files/nist_economic_contribution _report_final.pdf.

NIST. 2017b. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis—2017*. NIST Interagency/Internal Report (NISTIR)—85-3273-32. U.S. Department of Commerce, Washington, D.C.

NPS (National Park Service). 2006. *Life-Cycle Business Practices, Volume 1: Strategic Overview of Life-Cycle Business Practices*. U.S. Department of the Interior, Washington, D.C.

NRC (National Research Council). 2004. *Investments in Federal Facilities: Capital Asset Management Strategies for the 21st Century*. The National Academies Press, Washington, D.C.

NRC. 2004. *Key Performance Indicators for Federal Facilities Portfolios: Federal Facilities Council Technical Report Number 147.* The National Academies Press, Washington, D.C.

NRC. 2008. *Core Competencies for Federal Facilities Capital Asset Management Through 2020*. The National Academies Press, Washington, D.C.

NRC. 2014. *Furthering America's Research Enterprise.* The National Academies Press, Washington, D.C.

NRC. 2015. *Enhancing the Effectiveness of Team Science* (N.J. Cooke and M.L. Hilton, eds.). The National Academies Press, Washington, D.C.

Pasmore, W.A. 1988. *Designing Effective Organizations: The Sociotechnical Systems Perspective*. Wiley & Sons, New York, N.Y.

Plsek, P.E., and T. Greenhalgh. 2001. The challenge of complexity in health care. *British Medical Journal* 323(7313):625-628.

Pool, L.R., R.M. Wagner, L.L. Scott, D. RoyChowdury, R. Berhane, C. Wu, K. Pearson, J.A. Sutton, and W.T. Schaffer. 2016. Size and characteristics of the biomedical research workforce associated with U.S. National Institutes of Health extramural grants. *FASEB Journal* 30(3):1023-1036.

Ravid, K., R. Faux, B. Corkey, and D. Coleman. 2013. Building interdisciplinary biomedical research using novel collabortives. *Academic Medicine* 2(88):179-184.

Reeves, L., L.M. Dunn-Jensen, T.T. Baldwin, M.V. Tatikonda, and K. Cornetta. 2013. Partnership between CTSI and business schools can promote best practices for core facilities and resources. *Clinical and Translational Science* 6(4):297-302. doi: 10.1111/cts.12059.

RICS. 2012. *Raising the Bar: Enhancing the Strategic Role of Facilities Management*. Parliament Square, London, UK.

Rockey, S.J. 2014. Mentorship matters for the biomedical workforce. *Nature Medicine* 20(6):575. doi: 10.1038/nm0614-575.

Sargent, J.F. 2018. *Global Research and Development Expenditures: Fact Sheet*. Congressional Research Service, Washington, D.C.

Sawhill, R. 2008. "Strategic Facility Planning: Get Out of the Weeds, and Align Your Workplace with Your Business Needs." IFMA World Workplace 2008 presentation. https://www.slideshare.net/bob_sawhill/ifma-world-workplace-strategic-facility-planning.

Schilder, D. 2013. "Strategic Planning Process: Steps in Developing Strategic Plan." Harvard Family Research Project. Full Gospel Businessmen's Training. http://www.fgbt.org/Leadership-Principles/strategic-planning-process-steps-in-developing-strategic-plans.html.

Smith, K.A. 2008. Laws, leaders, and legends of the modern National Library of Medicine. *Journal of the Medical Library Association* 96(2):121-133. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2268223/.

Smith, U., K. Sipido, C. Dive, and L. Nicod. 2011. Alliance for biomedical research in Europe. *EMBO Molecular Medicine* 3:505-506.

Stanford University. 2005. *Guidelines for Life Cycle Cost Analysis.* Palo Alto, Calif.

Stanford University. 2017a. "Capital Plan and Capital Budget." Chapter 4 in *Stanford University Budget Plan 2017/18.* https://bondholder-information.stanford.edu/pdf/BudgetBookFY18.pdf.

Stanford University. 2017b. "Planned Research Building Designed for Innovation, Collaboration." Modified October 19. https://med.stanford.edu/news/all-news/2017/10/planned-research-building-designed-for-innovation-collaboration.html.

Toole, A.A. 2007. Does public scientific research complement private investment in research and development in the pharmaceutical industry? *Journal of Law and Economics* 50:81-104. http://sciencepolicy.colorado.edu/students/envs_5100/Toole2007.pdf.

Toole, A.A. 2012. The impact of public basic research on industrial innovation: Evidence from the pharmaceutical industry. *Research Policy* 41(1):1-12. http://www.sciencedirect.com/science/article/pii/S004873331100117X.

Turpen, P.B., P.E. Hockberger, S.M. Meyn, C. Nicklin, D. Tabarini, and J.A. Auger. 2016. Metrics for success: Strategies for enabling core facility performance and assessing outcomes. *Journal of Biomolecular Techniques* 27(1):25-39.

United for Medical Research. 2018. "NIHs Role in Sustaining the U.S. Economy." January. http://www.unitedformedicalresearch.com/wp-content/uploads/2018/02/NIHs-Role-in-Sustaining-the-U.S.-Economy-2018-Update-FINAL.pdf.

USDA (U.S. Department of Agriculture). 2012. *The USDA Agricultural Research Service Capital Investment Strategy*. http://www.aplu.org/members/commissions/food-environment-and-renewable-resources/board-on-agriculture-assembly/policy-board-of-directors/baapbd-minutes/ars_capital_investment_strategy.pdf.

Valantine, H.A. 2016. "NIH Advisory Committee to the Director: Working Group on Diversity Update." NIH Chief Officer for Scientific Workforce Diversity, National Institutes of Health, Bethesda, Md. December 8.

Wagner, J., and D. Watch. 2017. *Innovation Spaces: The New Design of Work.* Brookings Institution and Project for Public Spaces, Washington, D.C., and New York.

Wang, L., X. Wang, and N.J. Philipsen. 2017. Network structure of scientific collaborations between China and the EU member states. *Scientometrics* 113(2):765-781. doi: 10.1007/s11192-017-2488-6.

Watson, C.R. 2017. Assessing and addressing US health security risks. *Health Security* 15(1):15-16. doi: 10.1089/hs.2016.0102.

Williams, S. 2016. Building a translational powerhouse in China—Advertising feature. *Science* 361(6406). https://www.sciencemag.org/features/2016/06/building-translational-medicine-powerhouse-china.

Woofenden, T. 2018. "Allen Institute's Workplace Design for High-Throughput Neuroscience Research." *Tradeline*. June 6. https://www.tradelineinc.com/reports/2018-6/allen-institutes-workplace-design-high-throughput-neuroscience-research.

Yu, M.L., S. Hamid, M.T. Ijab, and H.P. Soo. 2009. The E-Balanced Scorecard (e-BSC) for measuring academic staff performance excellence. *Journal of Higher Education* 57:813-828.

Appendixes

A

Statement of Task

At the request of the Office of Research Facilities Development and Operations, National Institutes of Health, the National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee to: (1) identify facilities in greatest need of repair or those most impacting mission implementation; (2) assess the rationale and composition of projects to bring the NIH main campus facilities up to current standards or acceptable operational performance which meet mission objectives; (3) evaluate at a high level the completeness, accuracy, and relevance of cost estimates (already developed by/for NIH) for proposed capital projects; and (4) identify potential factors and approaches that the NIH should consider in developing a comprehensive capital strategy for its main campus portfolio of facilities. It is desired that the study identify approaches based on five (5), ten (10), and twenty (20) year prioritization outlook.

In addition, to better inform sustainment of NIH's main campus and capital planning, the study committee shall review comparable available facility condition methodologies and metrics of other federal agencies at an overall portfolio level, and provide recommendations in determining the minimum levels of funding required to sustain NIH's assets at an overall portfolio level.

B

Committee Biographical Information

KENNETH W. KIZER, M.D., M.P.H., *Chair*, is a distinguished professor and director of the Institute for Population Health Improvement (IPHI) at the University of California, Davis. Dr. Kizer is an internationally respected healthcare leader and an elected member of the National Academy of Medicine and of the National Academy of Public Administration. Among his multiple roles at IPHI, he serves as the chief medical officer for the California Department of Managed Health Care, director of the California Cancer Reporting and Epidemiologic Surveillance Program, and Chief Quality Improvement Consultant for the Medi-Cal Quality Improvement Program. Dr. Kizer is a highly seasoned physician executive whose diverse professional experience includes senior positions in the public and private sectors, academia, and philanthropy. Among his previous positions are founding president and CEO, National Quality Forum; chairman, CEO, and president, Medsphere Systems Corporation (a leading commercial provider of open source health information technology); Under Secretary for Health, U.S. Department of Veterans Affairs and chief executive officer of the nation's largest healthcare system (in which capacity he engineered the internationally acclaimed transformation of the Veterans Healthcare System in the late1990s); director of the former California Department of Health Services; director of the California Emergency Medical Services Authority; and chair of The California Wellness Foundation (the nation's largest philanthropy devoted exclusively to health promotion and population health improvement). Dr. Kizer is an honors' graduate of Stanford University and UCLA, the recipient of two honorary doctorates, and a fellow or distinguished fellow of 12 professional societies. He is board certified in six medical specialties and subspecialties, and has authored over 500 original articles, book chapters, and other reports. He is a veteran of the U.S. Navy and a former Navy diving medical officer and a recognized expert on medicine in wilderness and austere environments. He has chaired and served on numerous National Academies committees.

EDWARD J. DENTON is a Fellow of the American Institute of Architects (FAIA), with expertise in facilities including design, construction, maintenance operations, real estate, and security. Mr. Denton has extensive experience in management of design and construction for major healthcare and higher education projects as well as government agencies, developers, and large corporate clients. He has expertise in project development, design, program preparation, and administration, and is knowledgeable in seismic, energy, and environmental impact issues; building codes; ADA and OSHPD design; and construction requirements. From 2014 to the present, Mr. Denton has offered consulting services for developing and maintaining higher education and healthcare facilities. From 1998 to 2014, he was vice chancellor of Facilities Services, campus architect, and chief building official at the University of California, Berkeley.

DON EUGENE DETMER is university professor emeritus of health policy, emeritus senior vice president, and professor of medical education, Department of Public Health Sciences, School of Medicine, University of Virginia. Earlier, Dr. Detmer served as vice president and provost for Health Sciences at Virginia and VPHS at the University of Utah. He serves on a number of boards, among them the Corporation for National Research Initiatives and the journal, *Applied Clinical Informatics*. As the first president and CEO of the American Medical Informatics Association, he helped develop the medical subspecialty of clinical informatics offered by the American Board of Medical Specialties. Dr. Detmer has also served as the medical director for health policy and advocacy for the American College of Surgeons. In the early 1990s, he was the Dennis Gillings Professor of health management at Cambridge University. While there, Dr. Detmer served as a consultant to the British Parliament to review its national health information technology (HIT) strategy and assisted the Hospital Authority of Hong Kong with its HIT infrastructure. He also led the European "Informed Patient Project." Earlier, while chair of the U.S. National Committee on Vital and Health Statistics (NCVHS), Dr. Detmer created its national health information infrastructure work group that envisioned secure integrated electronic health records for medical care and public health as well as personal use, including national coordination. He also chaired the Institute of Medicine board on healthcare services for 8 years and was liaison to the *To Err Is Human* and *Crossing the Quality Chasm* reports. Dr. Detmer chaired the reports *The Computer-Based Patient Record: An Essential Technology for Health Care* and served on other study committees. In the mid-1990s, he founded the Blue Ridge Academic Health Group. While at Wisconsin, Dr. Detmer was central in creating a master's degree program in Administrative Medicine, and as a surgery resident at Duke, he was instrumental in fostering the modern era of ambulatory surgery as well as surgical physician assistants. He is an expert in medial tibial stress and chronic compartment syndromes. Dr. Detmer is the recipient of the Morris Collen Medal from ACMI, the Walsh McDermott Award from the National Academy of Medicine (then IOM) and is an honorary member of the American Academy of Nursing and the American Academy of Physician Assistants.

LAURA KATHRYN FIDLER, M.P.H., is a consultant at AMC Strategies, LLC. Ms. Fidler has 30 years' experience in academic health center master planning; clinical, educational, and research facilities construction/renovation; capital budgeting; and space planning. She gained this expertise through working in several functions at one institution for 24 years—University of Cincinnati (UC) Academic Health Center—followed by 7 years of providing strategic planning consulting services for a number of top institutions. Specific relevant experience includes the development and implementation of a $480 million, 10-year master plan of new construction and renovated space for the academic health campus. Through successful negotiations with four colleges and four hospital partners, a master plan was created to address the center's future teaching, clinical, and research needs. The largest phase of the project was a million-square-foot renovation of the Medical Sciences Building, the largest federally funded college of medicine ever constructed. Ms. Fidler led the space planning, design, swing space strategies, and capital budgeting for this project, resulting in the creation of new laboratories, classrooms, study space, animal facilities, and an upgraded mechanical infrastructure. To address growth and swing space needs, she directed the acquisition, renovation, and implementation of new satellite campuses. Ms. Fidler currently consults with national academic health centers to develop and implement strategic plans for institutional, departmental, and clinical service lines.

G. EDWARD (EDD) GIBSON, JR., is Professor and Sunstate Chair of Construction Management and Engineering in the School of Sustainable Engineering and the Built Environment (SSEBE) at Arizona State University (ASU). Dr. Gibson served as the school director from 2011 to 2018 and before that as programs chair of the Del E. Webb School of Construction from 2009-2011. In addition to ASU, he has served on the faculty of North Carolina State University, University of Texas, Austin, and University of Alabama, Tuscaloosa. Dr. Gibson's educational background includes a B.S. and a Ph.D. in civil engineering from Auburn University and an M.B.A. from the University of Dallas. He has been principal investigator (PI) or co-PI on over $9.5 million worth of funded research in his career. Dr. Gibson's research and teaching interests include front end planning, organizational change, asset management, alternative dispute resolution, and risk management, and he has received several awards for research excellence including the Construction Industry Institute's (CII's) Outstanding Researcher twice. Dr. Gibson has authored or co-authored over 230 publications, taught over 210 short courses to industry, and given more than 250 presentations in his career. He has been active on many national committees, among them a National Research Council (NRC) committee investigating project management practices at the U.S. Department of Energy, the Architectural Engineering Institute, and he also served as a Fulbright senior specialist in Norway in fall 2004. Dr. Gibson was awarded the 2016 ASCE R. L. Peurifoy Award for outstanding research. He has several years of industry experience and is a licensed professional engineer in Texas. Dr. Gibson is an elected member of the National Academy of Construction and a fellow in the American Society of Civil Engineers and through January 2019 was a member of the NRC Board on Infrastructure and the Constructed Environment.

SANJIV B. GOKHALE, P.E., is a professor of civil engineering and director of graduate studies in construction management at the Department of Civil and Environmental Engineering, Vanderbilt University. Prior to Vanderbilt University, Dr. Gokhale was a tenured associate professor in the Construction Management program at the Purdue University School of Engineering, Indianapolis, Indiana. He has over 15 years of consulting experience, related to design and construction. Dr. Gokhale is a registered professional engineer in New York state. He is the co-author of *Trenchless Technology: Pipeline and Utility Design, Construction, and Renewal*, published by McGraw Hill in 2005, and the author of *Construction Management of Healthcare Projects*, published by McGraw Hill in 2014. Dr. Gokhale is the recipient of the 2009 Distinguished Professor Award by the Construction Industry Institute (CII). He was elected as a fellow of the American Society of Civil Engineers (ASCE) in 2009 and is a current member of the NRC Board on Infrastructure and the Constructed Environment.

MICHAEL HARBER, P.E., is vice president for facilities management at St. Jude Children's Research Hospital in Memphis, Tennessee. Mr. Harber has served in that position for 13 years and has been at St. Jude since 2000. While at St. Jude, he has been the director of facilities operation and maintenance and a construction project manager. Mr. Harber has over 35 years of facilities management and engineering experience. Before joining St. Jude, he retired from the U.S. Navy after serving 20 years in the Navy Civil Engineer Corps, where he served in various facilities and construction management positions including the director of construction for a 1,000,000 SF, $185 million medical center and utilities plant replacement project and as the facilities director at the Navy's largest medical center and 19 satellite clinics. Mr. Harber has a very broad facilities and construction management background, having managed projects ranging from ammunition facilities to large hospitals and research buildings/vivariums. As vice president of facilities management, he was responsible for the departments of Design and Construction, Facilities Operations and Maintenance, Security, Biomedical Engineering, and Environmental Services. As the construction activity has increased, Mr. Harber has shed most of his responsibilities and now focuses on design and construction with particular emphasis on facilities planning. He has a master of engineering degree from the University of Florida and a bachelor of science degree in mechanical engineering from the U.S. Naval Academy. Mr. Harber is a registered professional engineer.

KERSTIN HILDEBRANDT-ABDIKARIM, M.S.H.S., is the vice president of research administration, Children's Research Institute (CRI) at Children's National Health System. In this capacity, Ms. Hildebrandt-Abdikarim is responsible for the strategic facility master planning of the current research facilities at the hospital campus as well as at the future Children's National Research Innovation Campus at the historic Walter Reed campus. In this capacity, she is responsible for the strategic facility master planning of the current research facilities at the hospital campus as well as at the future Research Innovation Campus at Walter Reed. Ms. Hildebrandt-Abdikarim's role encompasses strategic planning, administration and operations, facility development and construction, health and safety, the Research Animal Facility, financial management, regulatory affairs, human resource, IT, and communications, with a focus on LEAN research infrastructure development, integration, and optimization. Her current efforts are focused on laboratory densification, based on new lab space metrics and innovative ideas, to support 3 to 5 years of research program growth prior to the transition of the research programs to Walter Reed. Ms. Hildebrandt-Abdikarim received her B.S and M.S. in clinical research administration from George Washington University, School of Medicine and Health Sciences. Prior to joining Children's in 2001, she served as the administrator of the Division of Hematologic Malignancies and Bone Marrow Transplantation at the Dana-Farber Cancer Institute in Boston and as the administrative director of the Georgetown University, General Clinical Research Center. As president of a tenant organization in Boston, Ms. Hildebrandt-Abdikarim led the legal, financial, and development team of the only national tenant-governed Department of Housing and Urban Development (HUD)-sponsored HOPE II grant, resulting in $11 million of funding to purchase, renovate, and preserve a 276-unit, 23-story high-rise of affordable housing.

DOUGLAS W. KINCAID, P.E., is president and general manager, Applied Management Engineering (AME). Mr. Kincaid has helped set industry standards for facility condition assessments, maintenance and repair cost estimating, preventive maintenance, and asset management process. He and AME have been active in publishing facility management concepts. Mr. Kincaid has participated in the authorship of Managing the Facilities Portfolio and Maintenance Management Audit. He also directed the development of an RSMeans, Facilities' Maintenance and Repair Cost Data, which includes preventive maintenance standards developed by AME. Mr. Kincaid also was a member of the review committee for the National Research Council's publication, *Stewardship of Federal Facilities*.

THOMAS L. MITCHELL, JR., is senior vice president/COO of FM3IS Associates, LLC, San Antonio, TX. At FM3IS, Mr. Mitchell manages client-facing teams retained to develop and deliver services in the areas of facility portfolio performance, workforce capability development, and organization functionality alignment. From 2008 to 2014, he was lead associate, Facilities and Asset Management Consulting Services, with Booz Allen Hamilton, where he led technical consulting teams who collaborated with clients and other Booz Allen colleagues to develop vision, strategies, courses of action, and practical solutions that shape, improve, and optimize the built environment. Mr. Mitchell is a retired Lt. Col. in the U.S. Air Force, having spent 20 years of leading and managing programs directing the development, acquisition, and sustainment of facilities at military installations throughout the United States, Europe, Asia, and the Middle East.

KIRK PAWLOWSKI received his master of architecture degree from the University of Oregon and is a nationally respected academic health and life sciences architect practioner and former principal at the Portland, Oregon-Seattle, Washington firm SRG Partnership. As assistant vice provost for capital resource planning at the University of Washington (UW), Mr. Pawlowski served as a member of the UW President's Environmental Stewardship Committee (UWESC) and the UW Architectural Commission. His responsibilities include chairing the UWESC Implementation Work Group and the UW "Energy Future" Planning Workgroup. Mr. Pawlowski was responsible for the development and management of the UW 10-Year Capital Plan—UW's "One Capital Plan"—and led the successful integration of UW Academic Medical Center and UW School and College academic programs, including development and implementation of a new seismic-resilience capital investment program, within UW's biennial and long-range capital and operating resource allocation process. As executive director for capital planning and development at Washington State University (WSU) and Oregon State University (OSU)—the Land Grant universities of the Pacific Northwest—Mr. Pawlowski worked closely with WSU President Elson Floyd and academic faculty and staff to guide development of 800,000 gross square feet of new, state-of-the-art biomedical research facilities on the Pullman, Washington, campus, including the WSU College of Veterinary Medicine Global Animal Health facilities in collaboration with the Bill and Melinda Gates Foundation in Pullman, Washington, as well as development of a new WSU School of Medicine and new facilities for the WSU Schools of Pharmacy and Nursing at WSU's health sciences campus in Spokane, Washington. At Oregon State University, Mr. Pawlowski led the development of the Oregon State University (OSU) long-range capital plan and a new OSU campus in Bend, Oregon, in coordination with the State of Oregon Governor's Office and the Oregon Legislature. Mr. Pawlowski also served as the Oregon Health and Science University (OHSU) director of planning and real estate, and guided development of clinical and research facilities and established design standards for new buildings and renovations on the Marquam Hill and South Waterfront Campuses, as well as the federal Oregon Primate Research Center located in Beaverton, Oregon.

WILLIAM R. SEED is a senior vice president, facility design and construction, at Jackson Health System in Miami, Florida. In that position, Mr. Seed provides leadership for a $1.5 billion capital program delivering six signature projects in 4 years, including two new, full-service specialty hospitals renovating four existing hospitals to enhance service as the Miami-Dade County safety net healthcare provider. From 2014 to 2017, he was executive project integration with Walt Disney Imagineering, leading a program delivery transformation employing Lean Integrated Project Delivery methodologies. Mr. Seed has published two books and two white papers on transformational change in the construction industry, each centered on Lean principles and Integrated Project Delivery. In 2014, he was inducted into the National Academy of Construction recognizing this effort. Mr. Seed has been member of the board of directors and past chair for the Lean Construction Institute for 7 years and was awarded the Pioneer Award in 2012. Along with his B.S. in mechanical engineering, commercial general contractor license, and master electrical license, Mr. Seed has functioned in numerous roles from physical plant operations to capital and real estate development for two national healthcare systems with over 250 combined campuses.

SARAH SLAUGHTER is a recognized expert on resilience and sustainability for the built environment. Dr. Slaughter is the CEO and founder of the Built Environment Coalition, a research and education nonprofit (501c3) focused on community sustainability and resilience. She currently serves on the Green Building Advisory Committee (GBAC) to the U.S. General Services Administration on sustainable technologies and practices for the federal built facilities portfolio. Dr. Slaughter currently advises federal agencies on strategies for improving resilience, and she is a subject matter expert on urban infrastructure resilience for several research projects. In 2015, Dr. Slaughter was a visiting lecturer in the MIT Department of Urban Studies and Planning, teaching and doing research on resilient communities. Before founding the Built Environment Coalition, she was the MIT Energy Initiative (MITEI) Associate Director for Buildings and Infrastructure, and co-founder and faculty head of the Sustainability Initiative in the MIT Sloan School of Management. Previously, Dr. Slaughter was founder and CEO of MOCA Systems, Inc., based on the construction simulation software system developed in her MIT research. Before MOCA, she was a MIT professor in the Department of Civil and Environmental Engineering, and earlier was a professor in the Department of Civil and Environmental Engineering at Lehigh University. Dr. Slaughter is currently a member of the National Academy of Engineering and the National Academy of Construction. She was previously on the NAS National Research Council (NRC) Board on Infrastructure and the Constructed Environment (BICE), the NAS DoD Standing Committee on Materials, Manufacturing, and Infrastructure, and the vice chair of the NRC Committee on Sustainable Critical Infrastructure Systems. Dr. Slaughter also served on the Massachusetts Sustainable Water Management Advisory Board, the Sustainability Committee in the International Facilities Management Association (IFMA), and several national and international advisory committees and editorial boards of professional publications. She currently serves on the Board of Directors for the Charles River Watershed Association, and previously served on the Board of Directors of Retroficiency, Inc.; Eastern Research Group/AEA Technology, Inc.; and MOCA Systems, Inc. Dr. Slaughter received her Ph.D., S.M., and S.B. from the Massachusetts Institute of Technology.

PHILIP E. TOBEY, F.A.I.A., F.A.C.H.A., is senior vice president of SmithGroupJJR, one of the nation's largest architectural/engineering firms. He has over 45 years of experience in healthcare planning and design for the country's leading academic medical centers and healthcare systems. In 2008, Mr. Tobey was appointed to the U.S. Defense Health Board, evidence of his federal and military healthcare expertise. Widely recognized as one of the profession's leaders in healthcare architecture, he has addressed many national and regional organizations concerning issues and trends that affect healthcare, including the American Society of Hospital Executives, American Society of Hospital Engineers, American Society of Military Engineers, and AIA Academy of Architecture for Health. Notable clients include the National Institutes of Health, numerous academic medical centers, all branches of service of the Department of Defense, major health systems (including Kaiser Permanente, Sutter, and Universal), and many regional and community healthcare providers. Recently, Mr. Tobey was appointed to two congressionally mandated independent review panels for DoD: Achieving World Class Medical Facilities and Strategy Drives Form and Function—An Assessment of Military Medical Construction. Prior to entering private practice, Mr. Tobey served as an officer with the U.S. Air Force Office of the Surgeon General with review responsibility for medical projects worldwide, and where for almost a year, he was on special assignment to the White House.

C

Committee Activities

MEETING 1: MARCH 20-21, 2018
NATIONAL INSTITUTES OF HEALTH, BETHESDA, MARYLAND

Day One: Building 31

Orientation to NIH
Paul A. Sieving, M.D., Ph.D., NAM, Director, NEI
Dan Wheeland, P.E., Director, Office of Research Facilities
The Intramural Research Program (IRP) at NIH: Scope and Scale
Michael Gottesman, M.D., NAM, NIH Deputy Director for Intramural Research
Clinical Research at the Clinical Center
John Gallin, M.D., NAM, Associate Director for Clinical Research and CSO NIH Clinical Center
NIH Bethesda Campus Master Plan
Dan Wheeland, Director, Office of Research Facilities
Animal Facilities
Susan Roberts, Facilities Planning and Programming Branch Chief
Institute/Center/Office Leadership and Operations Building
Dan Wheeland, Director, Office of Research Facilities
Emerging Scientific Needs at the NIH
Michael Gottesman, M.D., NAM, NIH Deputy Director for Intramural Research
Capital Projects: On Deck, Shovel Ready, and Emerging
Daniel Cushing, Chief Architect, Office of Research Facilities
Annual Budgets: Building and Facilities, Facilities Maintenance, and Process
Daniel Cushing, Chief Architect, Office of Research Facilities
Facilities Working Group and Research Facilities Advisory Committee
Campus Driving Tour

Day Two: Clinical Center

Tour of Clinical Center
MGen James K. Gilman USA (ret.), M.D., CEO, NIH Clinical Center

Building 31

Questions about Clinical Center
MGen James K. Gilman USA (ret.), M.D., CEO, NIH Clinical Center
Federal Real Property Issues
Michael Armes, Assistant Director, Physical Infrastructure, Government Accountability Office

MEETING 2: MAY 15-16, 2018
NATIONAL INSTITUTES OF HEALTH, BETHESDA, MARYLAND

Day One: Building 35, Porter Neuroscience Research Center

Discussion with Committee
Francis Collins, NAS/NAM, Director, National Institutes of Health
Procurement Strategies and Guidelines
Dan Wheeland, Director, Office of Research Facilities
Project Selection and Execution
Daniel Cushing, Chief Architect, Office of Research Facilities
Facilities vis-à-vis Scientific Mission
Michael Gottesman, M.D., NAS/NAM, NIH Deputy Director for Intramural Research
Tours of Porter Neuroscience Research Center: Vivarium (Building 14/28 Complex); Infrastructure Core

Day Two: Building 31

NIH Budget
Neil Shapiro, Budget Director, NIH
Capital Budgeting in Other Federal Agencies
Mark Weatherly, Specialist Executive—Federal, Deloitte Consulting
Biowulf: High-Performance Computing at NIH
Andy Baxevanis, Director of Computational Biology, Office of Intramural Research
Bioinformatics and High-Performance Computing
Stephanie Hixson, P.E., Deputy Director, Division of Design and Construction Management, Office of Research Facilities
Animal Facilities at NIH
Richard G. Wyatt, M.D.,; Deputy Director, Office of Intramural Research

CONFERENCE CALL WITH NIH OFFICE OF RESEARCH FACILITIES: JULY 9, 2018

Discussion of Backlog of Maintenance and Repair
Dan Wheeland, P.E., Director, Office of Research Facilities, NIH
James Lewis, P.E., Office of Research Facilities, NIH

MEETING 3: AUGUST 8-9, 2018
KECK CENTER OF THE NATIONAL ACADEMIES, WASHINGTON, D.C.

Capital Planning at the National Aeronautics and Space Administration
Calvin Williams, Assistant Administrator for Strategic Infrastructure, NASA
Capital Planning at the National Institute of Standards and Technology
R.C. "Skip" Vaughn, Director, Office of Facilities and Property Management, and Chief Facilities Management Officer, NIST
Capital Planning at the USDA Agricultural Research Service
Simon Liu, Ph.D., Associate Administrator, Research Management and Operations, ARS
Overview of the U.S. Naval Research Laboratory
Dr. Bruce G. Danly, Director of Research, NRL
Comparison of NIH Deferred Maintenance to That of Other Federal Agencies
Raymond Dufresne, Senior Solution Architect, Accruent, LLC
Q&A Session with NIH
Dan Wheeland, P.E., Director, Office of Research Facilities, NIH

MEETING 4: SEPTEMBER 25-26, 2018
KECK CENTER OF THE NATIONAL ACADEMIES, WASHINGTON, D.C.

General Discussion
Dan Cushing, Chief Architect, Office of Research Facilities, NIH
James Lewis, Office of Research Facilities, NIH
Q&A session with NIH
Dan Wheeland, PE, Director, Office of Research Facilities, NIH

MEETING 5: JANUARY 10-11, 2019
ARNOLD AND MABEL BECKMAN CENTER, IRVINE, CALIFORNIA

Q&A session with NIH
Dan Wheeland, PE; Director, Office of Research Facilities, NIH
Paul Sieving, MD, NAM; Director, Facilities Working Group and Director, NEI
James Gilman, MD; CEO, Clinical Center

D

Data on NIH Clinical Center

TABLE D.1 Inpatient Census and Length of Stay and Nurse Staffing in the Clinical Center

	Available Beds	FY2016 ADC	FY2016 Nurse Staffing	FY2016 ALOS	FY2017 ADC	FY2017 Nurse Staffing	FY2017 ALOS	FY2018 Projected ADC[a]	FY2018 Nurse Staffing	FY2018 ALOS
1NW: Pediatrics	18	10.2	28.0	7.7	9.3	32.1	8.1	9.0	38.5	7.9
1SE: Alcohol/Behav. Health	10	7.7	13.1	19.4	7.8	15.2	18.6	6.5	14.1	25.3
1SW: Ped. Behav. Health	4	2.3	11.6	48.8	1.7	11.4	42.7	3.1	11.4	53.7
3NE: Hem.-Onc. Transplant	24	22.0	54.4	16.8	17.5	70.6	16.9	15.7	57.2	14.5
3NW: Adult Oncology	26	18.5	53.1	6.4	18.1	48.5	6.5	19.4	52.0	7.0
3SEN: Adult Oncology	10	4.7	16.0	7.8	4.4	17.4	7.5	5.3	19.9	8.6
3SW: ICU	14	6.0	34.7	36.0	5.4	34.7	40.5	5.5	34.7	27.6
5NES: Special Clinical Studies	3	1.3	10.0	7.3	0.7	10.0	5.4	0.9	10.0	6.2
5NW: General Medicine	27	12.9	26.4	4.1	10.5	25.8	4.2	11.0	22.9	4.4
5SE: Medicine—Telemetry	26	17.2	40.0	7.9	14.9	40.7	8.1	15.0	35.6	7.3
5SWN: Metabolic	5	3.9	10.0	5.5	2.2	10.0	4.6	3.2	10.0	4.1
7SE: Adult Behav. Health	20	11.9	27.7	58.6	10.8	26.4	69.7	12.8	27.9	98.1
7SWN: Neurology/Sleep Lab	12	8.2	15.5	7.3	8.0	21.1	6.6	6.7	22.8	8.1
7SWS: Metabolic	1	0.1	5.0	0.0	0.2	5.0	4.7	0.4	5.9	3.0
TOTAL	200	126.7	345.5	8.7	111.5	368.9	8.8	114.4	362.9	8.7

[a] FY 2018 projected based on data from October 1 through April 23.
^Staffing is based on census and acuity.
NOTE: ADC, average daily census; ALOS, average length of stay; FY, fiscal year.

TABLE D.2 Outpatient Activity and Nurse Staffing

Census Location	FY 2016 Visits	FY 2016 Nursing Staff	FY 2017 Visits	FY 2017 Nursing Staff	FY 2018 Projected Visits[a]	FY 2018 Nursing Staff
1NWDH: Pediatrics	2,514	4.4	2,253	6.4	1,981	7.7
3SEDH: Oncology	10,136	21.7	9,444	22.7	10,125	26.7
5SWDH: Oncology	6,281	14.8	5,173	13.8	6,303	16.4
Day Hospital Subtotal	*18,931*	*40.9*	*16,870*	*42.9*	*18,409*	*50.8*
1HALC: Alcohol	1,678	2.0	1,222	3.0	1,639	2.5
1HPED: Pediatrics	6,482	7.6	5,743	8.1	5,477	12.0
OP1SW: Peds Behav. Health	0	n/a	0	n/a	79	—[c]
OP03: Oncology and Oral Surgery	6,710	7.0	6,082	7.0	5,564	8.6
OP04: Behavioral Health	3,172	9.3	3,933	9.3	3,990	11.1
OP05: ENT, Neurology	5,870	6.0	4,817	6.0	5,219	8.0
OP05SWN: Metabolic	513	—	483	—	803	—[d]
OP05VC: Vaccine Evaluation	1,362	1.0	2,724	—	2,848	—[e]
OP06: Virtual Testing	220	—	148	—	88	—[f]
OP07: Cardiology and Hem./Onc.	5,688	5.5	5,279	5.5	4,384	6.7
OP07SWS: Metabolic	582	—	739	—	909	—[g]
OP08: Infectious Diseases	5,208	11.8	4,959	10.8	5,255	16.0
OP09: Med./Surg. Specialties	9,010	9.3	8,480	7.6	8,458	11.0
OP10: Ophthalmology	6,149	7.0	5,731	6.0	5,541	8.0
OP11: Allergy and Infectious Diseases, and Genetic Eye Disease	4,858	11.3	4,208	11.3	3,566	13.5
OP12: Medical Oncology	10,126	9.0	9,149	9.5	10,685	11.6
OP13: Derm. and Med. Onc.	4,065	3.0	4,061	3.6	3,616	4.0
OPDEN: Dental	3,645	1.0	3,512	2.0	2,773	3.0
OPRAD: Radiology	5,879	3.0	4,189	2.6	4,656	2.6
Clinic Subtotal	*81,217*	*93.8*	*75,459*	*92.3*	*75,550*	*118.6*
TOTAL	100,148	135	92,329	135	93,959	169

[a] FY 2018 projected based on data from October 1 through April 23.
[b] Staffing is based on patient activity, acuity, and a move toward a primary care model.
[c] OP1SW: Peds Behav. Health staffing numbers included in inpatient staffing.
[d] OP05SWN: Metabolic staffing included in 5SWN inpatient staffing numbers, as patients are seen on this unit.
[e] OP05VC: One patient care tech was provided by the CC in FY 2016; except for that one instance, all Vaccine Evaluation staffing is provided by NIAID.
[f] OP06: Virtual Testing staffing is provided by the institutes.
[g] OP07SWS: Metabolic staffing included in 7SWS inpatient staffing numbers, as patients are seen on this unit.

E

NIH Facilities: Cores

TABLE E.1 NIH IRP Core Facilities with Institute Affiliation(s) and Areas of Expertise

No.	Institute(s)	Core Facility Name	Areas of Expertise
1	NCI	LASP Animal Diagnostic Lab (ADL)	Animal Resources
2	NCI	LASP Animal Research Technology Support (ARTS)	Animal Resources
3	NCI	LASP Gnotobiotic Facility (GF)	Animal Resources
4	NCI	LASP Mouse Modeling and Cryopreservation (MMC)	Animal Resources
5	NCI	LASP Pathology/Histology Lab (PHL)	Animal Resources
6	NCI	LASP Small Animal Imaging Program (SAIP)	Animal Resources, Imaging and Microscopy
7	NCI	LASP Genome Modification Core (GMC)	Animal Resources, Genetics and Genomics
8	NCI	Advanced Biomedical Computing Center (ABCC)	Bioinformatics
9	NCI	CCR Collaborative Bioinformatics Resource (CCBR)	Bioinformatics
10	NCI	Genomics and Bioinformatics Group (GBG)	Bioinformatics
11	NCI	Statistical Consultation Group (SCG)	Bioinformatics
12	NCI	Biophysics Resource (SBL)	Chemistry and Structural Biology

No.	Institute(s)	Core Facility Name	Areas of Expertise
13	NCI	CBL Chemistry Support Group	Chemistry and Structural Biology
14	NCI	Molecular Modeling Core (LCB)	Chemistry and Structural Biology
15	NCI	SAXS Core Facility	Chemistry and Structural Biology
16	NCI	Synthetic Biologics Core	Chemistry and Structural Biology
17	NCI	Blood Processing Core	Clinical Research Support
18	NCI	Clinical Support Laboratory	Clinical Research Support
19	NCI	Laboratory of Cell-Mediated Immunity	Clinical Research Support
20	NCI	Collaborative Protein Technology Resource—Nanoscale Protein Analysis	Clinical Research Support, Single Cell Proteomics
21	NCI	Molecular Targets Core	Clinical Research Support, Proteins and Proteomics
22	NCI	CCR-Frederick Flow Cytometry Core Facility	Flow Cytometry
23	NCI	Clinical Support Laboratory—Flow Cytometry Section	Flow Cytometry, Clinical Research Support
24	NCI	Flow Cytometry Core (LGI)	Flow Cytometry
25	NCI	Vaccine Branch Flow Cytometry Core	Flow Cytometry
26	NCI	CCR Genomics Core	Genetics and Genomics, Single Cell Analysis
27	NCI	Genomics Technology Laboratory	Genetics and Genomics
28	NCI	Molecular Cytogenetics Core Facility	Genetics and Genomics
29	NCI	NCI Cancer and Inflammation Program—Microbiome and Genetics Core (CIP-MGC)	Genetics and Genomics
30	NCI	Sequencing Facility	Genetics and Genomics
31	NCI	CCR Confocal Microscopy Core Facility	Imaging and Microscopy
32	NCI	Electron Microscopy Laboratory (EML)	Imaging and Microscopy
33	NCI	High-Throughput Imaging Facility (HiTIF)	Imaging and Microscopy
34	NCI	LCMB Microscopy Core	Imaging and Microscopy
35	NCI	LGCP Microscopy Core	Imaging and Microscopy
36	NCI	LRBGE Optical Microscopy Core	Imaging and Microscopy
37	NCI	Optical Microscopy and Analysis Lab (OMAL)	Imaging and Microscopy
38	NCI	Clinical Pharmacology Program (CPP)	Pharmacology
39	NCI	Preclinical Pharmacokinetics Core	Pharmacology
40	NCI	Pharmacogenetics Core	Pharmacology

No.	Institute(s)	Core Facility Name	Areas of Expertise
41	NCI	Collaborative Protein Technology Resource—Mass Spectrometry	Proteins and Proteomics
42	NCI	Protein Characterization Laboratory (PCL)	Proteins and Proteomics
43	NCI	Protein Expression Laboratory (PEL)	Proteins and Proteomics
44	NCI	Rare Cell Isolation Unit	Single Cell Analysis
45	NHLBI	Animal MRI Core	Animal Resources, Imaging and Microscopy
46	NHLBI	Animal Surgery and Resources Core	Animal Resources
47	NHLBI	Biochemistry Facility	Proteins and Proteomics, Chemistry and Structural Biology
48	NHLBI	Bioinformatics and Computational Biology Core	Bioinformatics
49	NHLBI	Biophysics Core	Chemistry and Structural Biology
50	NHLBI	DNA Sequencing and Genomics Core	Genetics and Genomics
51	NHLBI	Electron Microscopy Core	Imaging and Microscopy
52	NHLBI	Flow Cytometry Core	Flow Cytometry
53	NHLBI	iPSC Core	Stem Cell Biology and Technology
54	NHLBI	Light Microscopy Core	Imaging and Microscopy
55	NHLBI	Murine Phenotyping Core	Animal Resources, Imaging and Microscopy
56	NHLBI	Pathology Core	Animal Resources
57	NHLBI	Proteomics Core	Proteins and Proteomics
58	NHLBI	Transgenic Core	Animal Resources
59	NHLBI/Trans-NIH	Center for Human Immunology (CHI) (Trans-NIH)	Protein and Proteomics
60	NHLBI/Trans-NIH	Imaging Probe Development Center (Trans-NIH)	Animal Resources, Imaging and Microscopy
61	NIDDK	NIDDK Advanced Light Microscopy and Image Analysis Core (ALMIAC)	Imaging and Microscopy
62	NIDDK	NIDDK Advanced Mass Spectrometry Core	Proteins and Proteomics
63	NIDDK	NIDDK Biostatistics Program	Bioinformatics Biostatistics Computing
64	NIDDK	NIDDK Biotechnology Core	Proteins and Proteomics
65	NIDDK	NIDDK Clinical Laboratory Core	Clinical Research Support
66	NIDDK	NIDDK Clinical Mass Spectrometry Core	Clinical Research Support
67	NIDDK	NIDDK Genomics Core	Genetics and Genomics

No.	Institute(s)	Core Facility Name	Areas of Expertise
68	NIDDK	NIDDK Human Energy and Body Weight Regulation Core	Clinical Research Support
69	NIDDK	NIDDK Laboratory of Animal Sciences Section	Animal Resources
70	NIDDK	NIDDK Mouse Knockout Core	Animal Resources
71	NIDDK	NIDDK Mouse Metabolism Core	Animal Resources
72	NIDDK	NIDDK Electron Microscopy Core Facility	Imaging and Microscopy
73	NIEHS	NIEHS Computational Chemistry and Molecular Modeling Support Group	Chemistry and Structural Biology
74	NIEHS	NIEHS DNA Sequencing and Epigenomics Core	Genetics and Genomics
75	NIEHS	NIEHS Flow Cytometry Center	Flow Cytometry
76	NIEHS	NIEHS Fluorescence Microscopy and Imaging Center	Imaging And Microscopy
77	NIEHS	NIEHS Integrative Bioinformatics Support Group	Bioinformatics
78	NIEHS	NIEHS Knockout Mouse Core Laboratory	Animal Resources
79	NIEHS	NIEHS Mass Spectrometry Research and Support Group	Proteins and Proteomics
80	NIEHS	NIEHS Molecular Genomics Core Laboratory	Genetics and Genomics
81	NIEHS	NIEHS Protein Expression Core Laboratory	Proteins and Proteomics
82	NIEHS	NIEHS Viral Vector Core Laboratory	Proteins and Proteomics, Genetics and Genomics,
83	NIEHS	NIEHS X-ray Crystallography Core Laboratory	Chemistry and Structural Biology
84	NINDS/Trans-NIH	NIH Stem Cell Unit (Trans-NIH)	Stem Cell Biology and Technology
85	NINDS	NINDS EM Facility	Imaging and Microscopy
86	NINDS	NINDS Flow Cytometry Core	Flow Cytometry
87	NINDS	NINDS Light Imaging Facility	Imaging and Microscopy
88	NINDS	NINDS Protein/Peptide Sequencing Facility	Proteins and Proteomics
89	NINDS	NINDS Viral Production Core Facility	Proteins and Proteomics
90	NINDS/Trans-NIH	NIH NMR Facility (Trans-NIH)	Stem Cell Biology and Technology
91	NINDS	NIH MRI Research Facility (NMRF) (Trans-NIH)	Imaging and Microscopy
92	NIMH/NINDS	NIMH Functional MRI Core Facility (NINDS/NIMH)	Flow Cytometry
93	NIMH	NIMH Human Brain Collection Core (HBCC)	Cell Banking and Aliquoting
94	NIMH	NIMH Magnetic Resonance Spectroscopy Core (MRS)	Imaging and Microscopy

No.	Institute(s)	Core Facility Name	Areas of Expertise
95	NIMH	NIMH Magnetoencephalography (MEG) Core Facility	Clinical Research Support
96	NIMH	NIMH Scientific and Statistical Computing Core (SSCC)	Bioinformatics Biostatistics and Computing
97	NIMH	NIMH Transgenic Core Facility	Animal Resources
98	NIMH	NIMH Section on Instrumentation (SI) Core Facility	Clinical Research Support
99	NIAID	NIAID RTB Rocky Mountain Laboratories (RML) Electron Microscopy Unit	Imaging and Microscopy
100	NIAID	NIAID RTB Rocky Mountain Laboratories (RML) Genomics Unit	Genetics and Genomics
101	NIAID	NIAID RTB Rocky Mountain Laboratories (RML) Visual and Medical Arts Unit	Clinical Research Support
102	NIAID	NIAID RTB Protein Chemistry	Proteins and Proteomics
103	NIAID	NIAID RTB Biological Imaging	Imaging and Microscopy
104	NIAID	NIAID RTB Flow Cytometry	Flow Cytometry
105	NIAID	NIAID RTB Genomic Technologies	Genetics and Genomics
106	NIAID	NIAID RTB Structural Biology	Chemistry and Structural Biology
107	NHGRI	NHGRI Bioethics Core	Clinical Research Support
108	NHGRI	NHGRI Bioinformatics and Scientific Programming Core	Bioinformatics Biostatistics and Computing
109	NHGRI	NHGRI Cytogenetics and Microscopy Core	Imaging and Microscopy
110	NHGRI	NHGRI Embryonic Stem Cell and Transgenic Mouse Core	Animal Resources
111	NHGRI	NHGRI Flow Cytometry Core	Flow Cytometry
112	NHGRI	NHGRI Genomics Core	Genetics and Genomics
113	NHGRI	NHGRI Microarray Core	Genetics and Genomics
114	NHGRI	NHGRI Zebrafish Core	Animal Resources
115	CC/Trans-NIH	NIH Clinical Center Clinical Image Processing Service (CIPS)	Clinical Research Support
116	CC/Trans-NIH	NIH Clinical Center Department of Laboratory Medicine	Clinical Research Support
117	CC/Trans-NIH	NIH Clinical Center Department of Radiology and Imaging Sciences Laboratory of Diagnostic Radiology Research (LDRR)	Clinical Research Support
118	CC/Trans-NIH	NIH Clinical Center Department of Transfusion Medicine Cell Processing Section (CPS)	Clinical Research Support
119	CC/Trans-NIH	NIH Clinical Center Functional and Applied Biomechanics (FAB) Section	Clinical Research Support

No.	Institute(s)	Core Facility Name	Areas of Expertise
120	CC/Trans-NIH	NIH Clinical Center Metabolic Clinical Research Unit (MCRU)	Clinical Research Support
121	CC/Trans-NIH	NIH Clinical Center Pharmacy Department Investigational Drug Management	Clinical Research Support
122	CC/Trans-NIH	NIH Clinical Center Positron Emission Tomography (PET)	Clinical Research Support
123	NICHD	NICHD Microscopy Imaging Core	Imaging and Microscopy
124	NICHD	NICHD Biomedical Mass Spectrometry Core Facility	Proteins and Proteomics
125	NICHD	NICHD Molecular Genomics Core (MGC)	Genetics and Genomics
126	NICHD	NICHD Zebrafish Core	Animal Resources
127	NICHD	NICHD Computer Support Services Core	Bioinformatics
128	NICHD	NICHD Mouse Core	Animal Resources
129	NEI	Biological Imaging	Imaging and Microscopy
130	NEI	Flow Cytometry	Flow Cytometry
131	NEI	Genetic Engineering	Animal Resources
132	NEI	Histopathology Core	Animal Resources
133	NEI	Ocular Gene Therapy	Proteins and Proteomics
134	NEI	Visual Function	Animal Resources
135	NIDA	NIDA Electron Microscopy Core	Imaging and Microscopy
136	NIDA	NIDA Genetic Engineering and Viral Vector Core	Genetics and Genomics, Proteins and Proteomics
137	NIDA	NIDA Histology Core	Animal Resources
138	NIDA	NIDA Structural Biology Core	Chemistry and Structural Biology
139	NIAMS	NIAMS Flow Cytometry Group	Flow Cytometry
140	NIAMS	NIAMS Genomic Technology Unit	Genetics and Genomics
141	NIAMS	NIAMS Light Imaging Section	Imaging and Microscopy
142	NIAMS	NIAMS Translational Immunology Section	Clinical Research Support
143	NIA	NIA Confocal Imaging Facility	Imaging and Microscopy
144	NIA	NIA Flow Cytometry Unit	Flow Cytometry
145	NIA	NIA Gene Expression and Genomics Unit	Genetics And Genomics
146	NIA	NIA Nonhuman Primate Core	Animal Resources
147	NIDCD	Advanced Imaging Core	Imaging and Microscopy
148	NIDCD	Audiology Unit	Collaborative Resource; Clinical Support Services

No.	Institute(s)	Core Facility Name	Areas of Expertise
149	NIDCD	Genomics and Computational Biology Core	Genetics and Genomics, Bioinformatics, Biostatistics, Computing, Single Cell Analysis
150	NIDCD	Mouse Auditory Testing Core Facility	Animal Resources
151	NIBIB	NIBIB Molecular Tracer and Imaging Core Facility	Imaging and Microscopy
152	NIBIB	Biomedical Engineering and Physical Science (BEPS)	Imaging and Microscopy
153	NIBIB	NIBIB Advanced Imaging and Microscopy (AIM) Resource	Imaging and Microscopy
154	NIDCR	NIDCR Combined Technical Core	Flow Cytometry, Genetics and Genomics, Animal Resources
155	NIDCR	NIDCR Gene Transfer Core	Animal Resources
156	NIAAA	NIAAA Clinical Core Laboratory (CCL)	Clinical Research Support
157	NIAAA	NIAAA Clinical NeuroImaging Research Core (CNIRC)	Imaging and Microscopy, Clinical Research Support
158	NCATS/Trans-NIH	NCATS RNAi Screening Facility	Genetics and Genomics
159	ORS/Trans-NIH	Division of Veterinary Resources (DVR)	Animal Resources
160	ORS/Trans-NIH	Division of Veterinary Resources (DVR)—Pathology Service	Animal Resources, Imaging and Microscopy
161	ORS/Trans-NIH	NIH ORS DRS Radioactive Materials Control and Analysis Branch	Radiation Control and Analysis
162	ORS/Trans-NIH	NIH ORS DRS Regulatory Compliance Support Group	Regulatory Compliance
163	ORF/Trans-NIH	NIH ORF Mechanical Instrumentation and Design Fabrication Services	Lab Equipment
164	ORS/Trans-NIH	Division of Scientific Equipment and Instrumentation Services (DSEIS)	Lab Equipment
165	ORS/Trans-NIH	Division of Veterinary Resources (DVR)—Animal Surgery	Animal Resources
166	Trans-NIH	Natural Products Repository (DTP)	Chemistry and Structural Biology
167	Trans-NIH	NIH Intramural Sequencing Center (NISC)	Genetics and Genomics

NOTE: BMAR, Backlog of Maintenance and Repair; FRPC, Federal Real Property Council; MLP, multilevel parking; SF, square feet.

F

Facilities on Bethesda Campus

TABLE F.1 Key Characteristics and Condition of Facilities on Bethesda Campus

Facility Number	Use	FRPC Predominant Use	Year Constructed	Size (SF)	Replacement Value	BMAR	Condition Index
Building 01	Administrative	10—Office	1938	98,561	32,063,492	10,161,486	68.31
Building 02	Administrative	10—Office	1938	45,319	14,743,006	2,131,390	85.54
Building 03	Administrative	10—Office	1938	49,243	50,056,874	27,867	99.94
Building 04	Laboratory	74—Laboratories	1941	98,103	91,754,179	24,952,183	72.81
Building 05	Laboratory H	74—Laboratories	1941	99,850	93,388,120	9,977,210	89.32
Building 06	Laboratory	74—Laboratories	1938	84,350	78,891,506	2,125,117	97.31
Building 06A	Laboratory	74—Laboratories	1976	24,641	23,046,336	15,461,284	32.91
Building 06B	Animal Facility	74—Laboratories	1990	58,817	51,423,833	4,401,617	91.44
Building 08 and 08A	Laboratory H	74—Laboratories	1945	99,471	93,033,648	22,985,167	75.29
Building 10	Research	74—Laboratories	1952	2,991,310	2,344,158,529	578,839,408	75.31
Building 10—CRC	Healthcare	74—Laboratories	2005	1,779,729	732,336,647	4,454,907	99.39
Building 11 and 11A	Central Utiliti	50—Industrial	1951	290,488	330,613,940	24,899,348	92.47
Building 12	Office	60—Service	1950	62,485	20,686,504	9,989,661	51.71
Building 12A	Administrative	10—Office	1965	72,309	23,523,290	14,454,212	38.55
Building 12B	Administrative	60—Service	1979	33,027	10,744,219	4,171,259	61.18
Building 13	Office	60—Service	1950	251,367	81,773,762	13,860,988	83.05
Building 14A	Laboratory an	74—Laboratories	1951	79,045	34,925,533	10,719,613	69.31
Building 14B	Animal Research	74—Laboratories	1953	33,971	27,628,293	4,413,758	84.02
Building 14C	Animal Research	74—Laboratories	1953	26,318	21,404,181	5,015,995	76.57
Building 14D	Animal Research	74—Laboratories	1953	37,543	30,533,367	14,078,673	53.89
Building 14E	Animal Research	74—Laboratories	1953	27,042	21,993,003	2,586,289	88.24
Building 14F	Animal Research	74—Laboratories	1957	33,125	26,940,249	4,659,355	82.70
Building 14G	Animal Research	74—Laboratories	1957	26,376	21,451,352	2,628,019	87.75
Building 14H	Animal Research	74—Laboratories	1982	10,184	8,282,551	2,425,942	70.71
Building 15B1	Administrative	30—Family Housing	1938	4,033	1,148,000	248,514	78.35
Building 15B2	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	114,712	90.01
Building 15C1	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	166,483	85.50
Building 15C2	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	244,637	78.69
Building 15D1	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	127,731	88.87
Building 15D2	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	94,556	91.76
Building 15E1	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	89,105	92.24
Building 15E2	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	69,940	93.91
Building 15F1	Administrative	30—Family Housing	1938	4,033	1,148,000	167,469	85.41
Building 15F2	Administrative	30—Family Housing	1938	4,033	1,148,000	156,007	86.41
Building 15G1	Residence 3 B	30—Family Housing	1938	4,033	1,148,000	138,636	87.92
Building 15G2	Administrative	30—Family Housing	1938	4,033	1,148,000	104,352	90.91
Building 15H	Residence 3 B	30—Family Housing	1938	6,010	1,710,757	351,571	79.45
Building 15I	Residence 3 B	30—Family Housing	1938	6,010	1,710,757	319,405	81.33
Building 15K	Office	74—Laboratories	1930	14,839	13,878,681	449,376	96.76

Facility Number	Use	FRPC Predominant Use	Year Constructed	Size (SF)	Replacement Value	BMAR	Condition Index
Building 16	Administrative	10—Office	1949	24,843	8,081,831	2,721,480	66.33
Building 16A	Administrative	10—Office	1949	4,822	1,568,675	0	100.00
Building 17	Central Utiliti	50—Industrial	1948	7,651	5,371,398	193,585	96.40
Building 18	Laboratory	74—Laboratories	1950	5,176	4,841,031	97,625	97.98
Building 18T	Administrative	10—Office	1980	1,843	599,558	55,287	90.78
Building 21 and 21A	Laboratory an	74—Laboratories	1949	36,123	33,785,269	2,733,996	91.91
Building 22	Maintenance	10—Office	1952	15,810	5,143,249	1,792,964	65.14
Building 22A	Office	60—Service	1960	1,032	335,726	84,166	74.93
Building 25	Storage	41—Warehouses	1951	6,300	1,178,458	725,447	38.44
Building 28 and 28A	Laboratory	74—Laboratories	1951	28,800	13,513,400	2,675,515	80.20
Building 29	Laboratory	74—Laboratories	1960	89,028	83,266,476	30,211,863	63.72
Building 29A	Laboratory	74—Laboratories	1966	106,694	99,789,205	20,787,534	79.17
Building 29B	Laboratory	74—Laboratories	1994	102,700	109,783,651	5,892,443	94.63
Building 30 and Tower	Laboratory	74—Laboratories	1959	110,241	103,106,658	7,176,074	93.04
Building 31 and Wings	Administrative	10—Office	1962	592,903	196,065,808	139,552,782	28.82
Building 32	Laboratory H	74—Laboratories	1959	23,380	21,866,943	1,752,140	91.99
Building 33—C.W. Bill Y	Laboratory	74—Laboratories	2007	289,329	146,688,589	6,942,290	95.27
Building 35—Porter Ne	Laboratory H	74—Laboratories	2005	473,442	327,103,017	18,689,281	94.29
Building 37	Laboratory	74—Laboratories	1970	322,677	301,794,677	8,398,108	97.22
Building 38	Library	29—Other Institution	1962	236,530	192,367,613	37,849,234	80.32
Building 38A	Administrative	10—Office	1981	226,545	73,698,763	40,656,874	44.83
Building 40	Laboratory	74—Laboratories	2000	141,396	83,416,724	5,367,791	93.57
Building 41	Laboratory	74—Laboratories	1969	138,270	129,321,737	8,545,918	93.39
Building 41A	Laboratory	74—Laboratories	1969	3,502	3,275,365	391,259	88.05
Building 45	Administrative	10—Office	1994	537,015	174,699,689	11,339,954	93.51
Building 46	Central Utilities	50—Industrial	1962	11,526	4,686,993	1,771,126	62.21
Building 49	Laboratory	74—Laboratories	1992	274,509	256,743,911	36,710,065	85.70
Building 50	Laboratory	74—Laboratories	2001	565,459	210,875,973	20,791,062	90.14
Building 51—Fire Station	Fire/Police Station	60—Service	2003	21,724	7,571,967	376,773	95.02
Building 52	Central Utilities	50—Industrial	1950	689	1,678,704	90,378	94.62
Building 53	Central Utilities	50—Industrial	1950	3,968	1,613,568	191,908	88.11
Building 54	Central Utilities	50—Industrial	1950	168	168,914	143,641	14.96
Building 58	Central Utilities	50—Industrial	1950	57	165,023	94,273	42.87
Building 59—Electrical	Utility Plant	60—Service	2005	2,891	2,041,760	46,249	97.73
Building 60	Multiuse	80—All Other	1923	67,500	26,963,471	12,659,833	53.05
Building 61	Administrative	10—Office	1923	2,396	779,458	230,816	70.39
Building 61A	Administrative	10—Office	1923	900	292,785	93,291	68.14
Building 62	Multiuse	30—Family Housing	1990	70,448	20,053,142	2,551,838	87.27
Building 63—North Ele	Utility Plant	50—Industrial	2007	8,000	3,495,922	78,275	97.76
Building 64	Child Care Ce	60—Service	2001	15,449	5,384,797	648,140	87.96
Building 65—Family Lo	Housing—Dor	30—Family Housing	2005	27,583	7,851,442	759,667	90.32

Facility Number	Use	FRPC Predominant Use	Year Constructed	Size (SF)	Replacement Value	BMAR	Condition Index
Building 66	Other Special	29—Other Institution	2008	12,325	5,135,034	597,715	88.36
Building 66A	Other Special	29—Other Institution	2008	8,377	2,919,829	231,716	92.06
Building 67—Commerc	Guard House	60—Service	2007	18,110	6,312,297	94,537	98.50
Building 68—West Driv	Guard House	80—All Other	2007	782	1,059,232	20,935	98.02
Building 82	Administrative	10—Office	1966	15,785	5,135,117	969,725	81.12
Building MLP 6—Multiuse	Garage	66—Parking Structure	1969	280,206	45,577,778	7,308,784	83.96
Building MLP 7—Multiuse	Garage	66—Parking Structure	1979	137,578	22,378,177	2,136,550	90.45
Building MLP 8—Multiuse	Garage	66—Parking Structure	1993	465,276	75,680,915	7,958,706	89.48
Building MLP 9—Multiuse	Garage	66—Parking Structure	2007	351,034	57,098,527	955,337	98.33
Building MLP10—Multiuse	Garage	66—Parking Structure	2007	375,000	60,996,791	3,868,583	93.66
Building MLP11—Multiuse	Garage	65—Parking Structure	2008	118,334	19,247,985	1,277,295	93.36
Building T14—Storage	Maintenance	41—Warehouses	1994	4,000	748,227	131,637	82.41
Building T23	Storage	80—All Other	1990	5,376	1,005,618	167,203	83.37
Building T26	Storage	80—All Other	1993	2,371	443,512	515,644	(16.26)
Building T39—Fitness Center	Multiuse	80—All Other	1979	5,160	1,798,534	619,649	65.55
Building T46—Child Care	Child Care Center	80—All Other	1997	3,000	1,045,659	192,178	81.62
Northwest Child Care	Child Care Center	60—Service	2017	23,086	8,046,697	0	100.00
PNRC II		74—Laboratories	2014	571,003	260,277,347	0	100.00
Total				**13,484,051**	**7,542,411,228**	**1,251,180,380**	**83.41**

G

NIH Facilities: Space Utilization

TABLE G.1 Space Utilization by Category by Organizational Unit

	Usage Category						
IC or UNIT	ADMIN	ANIMAL	CLINICAL	LAB	OTHER	Total	% of Grand Total
CC	78,890	614	660,075	40,441	92,908	872,928	17.5%
CINIH					47,385	47,385	0.9%
CIT	32,907				57,850	90,758	1.8%
CSR	774				0	774	0.0%
DIR RES	15,710	8,177		805	861	25,553	0.5%
FAES	15,055				11,146	26,201	0.5%
FIC	22,883				479	23,361	0.5%
FNIH	441				143	585	0.0%
NCATS	4,525				0	4,525	0.1%
NCCIH	6,470			4,116	259	10,846	0.2%
NCI	90,690	37,375	6,250	360,157	1,040	495,512	9.9%
NEI	18,934	64,930	9	48,885	127	132,885	2.7%
NHGRI	27,673	814		56,336	1,610	86,434	1.7%
NHLBI	42,165	2,004	74	152,487	2,185	198,915	4.0%
NIA	11,375			7,579	0	18,954	0.4%
NIAAA	6,253			3,924	0	10,177	0.2%
NIAID	42,433	63,576		213,857	1,395	321,262	6.4%
NIAMS	14,803	1,266		43,054	497	59,620	1.2%
NIBIB	21,084		3,021	10,566	378	35,049	0.7%
NICHD	23,233	24,179		114,607	71	162,090	3.2%
NIDA	3,084			1,003	0	4,087	0.1%
NIDCD	16,837			27,034	29	43,900	0.9%
NIDCR	14,283	5,249		62,486	736	82,754	1.7%
NIDDK	32,715	4,755	211	166,680	283	204,645	4.1%
NIEHS	2,588		230	1,544	0	4,363	0.1%
NIGMS	34,396				0	34,396	0.7%
NIMH	39,789	1,304	1,923	95,030	99	138,144	2.8%
NIMHD	3,822			955	0	4,777	0.1%
NINDS	38,770	62,482	874	159,376	4,230	265,731	5.3%
NINR	13,305			5,595	420	19,319	0.4%
NLM	287,115				77,200	364,316	7.3%
OD	100,170				15,502	115,672	2.3%
OHR	22,976				3,073	26,049	0.5%
ORF	115,328	0	597	8,979	56,547	181,451	3.6%
ORS	133,248	146,164	0	19,312	258,401	557,125	11.1%
VACANT	30,934	5,690	91,032	186,491	17,415	331,561	6.6%
Grand Total	1,365,659	428,580	764,295	1,791,301	652,268	5,002,103	100%
	27%	9%	15%	36%	13%	100%	

H

Review of NIH Corporate Strategic Planning Process

PORTFOLIO MANAGEMENT OF THE BUILT ENVIRONMENT

Capital Investment Planning and Budgeting

Once management has used portfolio strategies to identify capital asset(s) that should be refurbished or replaced, a business case must be prepared to identify the most cost effective, most beneficial, and least risky course of action. Facility managers can work with organizational leadership to develop business cases to systematically consider capital asset upgrade financial costs, qualitative and quantitative benefits, and risks by project alternatives. Each alternative is evaluated independently and then compared side by side to facilitate management decision making. Typical outputs include Net Present Value (NPV), Return on Investment (ROI), Internal Rate of Return (IRR), and Payback Period. Qualitative factors are displayed graphically to show the level of expected benefits and possible risks.

After the business case has been made, numerous capital investments profiles can be developed to optimize capital asset condition/performance. By combining deferred maintenance, capital asset design life, and year of last replacement, NIH leadership can use different capital funding profiles to determine the resulting impact on capital asset condition and, therefore, capital asset performance.

- By combining deferred maintenance, capital asset design life, and year of last replacement, managers can use different capital investment funding profiles to determine the resulting impact on capital asset condition and, therefore, capital asset performance.
- To achieve desired capital asset performance, capital investment must not only be steady, but also high enough to make an impact.

The adaptation of the National Park Service (NPS) comparative evaluation approach toward optimizing fiscal and facility stewardship capability provides the decision-enabling capacity to successfully implement and sustain an enterprise-wide, facility portfolio investment planning and management program.

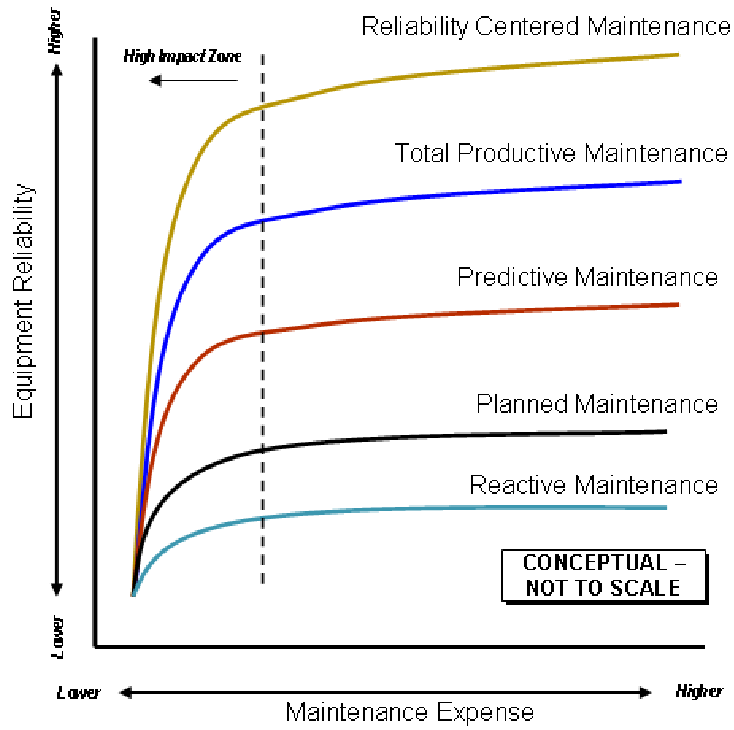


FIGURE H.1 Reliability Centered Maintenance. SOURCE: Courtesy of David Baglee, University of Sunderland.

Implementation and Execution

Once a decision is made to pursue capital investment, innovative procurement approaches and robust program management capabilities are required in the acquisition, operations and maintenance, and disposal of capital assets. Projects should be tracked by measuring cost, schedule, and technical progress, which could be accomplished through earned value management.

For existing capital assets and after investments are made, to keep capital assets running at optimum levels, an appropriate maintenance regime will ensure that the value of capital asset management is maintained. For the most critical capital assets, facility managers should go beyond planned or even predictive maintenance programs and strive for mature maintenance processes such as reliability centered maintenance (RCM), Figure H.1. RCM yields the highest level of equipment reliability for the least amount of maintenance expense. RCM can be the most cost-efficient maintenance program—it eliminates unnecessary equipment maintenance or system overhauls. However, RCM may have significant start-up costs associated with staff training and equipment needs (Gurumeta, 2007).

Performance Assessment and Improvement

To be truly successful, the organization must embrace performance measurement from top to bottom. Organizations that have used performance measurement as a management tool for improved results have employed many of the following practices:

- Periodic performance reviews at various levels within the organization,
- Budgeting based on performance measures,
- Communication of measurement results throughout the organization,

TABLE H.1 Snapshot of Common Measures

Metric Description	Standard	Metric Description	Standard
Facility Condition Index (FCI)	<0.05	Stockroom Turns/Year	2-3
Deferred Maintenance Backlog	Trend	Annual Training Hours	>40 hr
On-the-Job Wrench Time	>60%	Maintenance Cost/Replacement cost	3-4%
PM/CM Ratio	70/30	Percent Return Work	<5%
Unscheduled Maintenance Downtime	<2%	Mean Time Between Failures	Trend
PM Schedule Compliance	>95%	% Failures Assessed: Root Cause	>75%
CM Schedule Compliance	>90%	Maintenance OT Percentage	5-15%
Unscheduled Man-Hours	<10%	% WO Covered by Estimates	>90%
WO Turnaround Time	Trend	On-Site Supervisor Time	>65%
Emergency Response Time	<15 min.[2]	Stockroom On-Time Delivery	>97%
Stockroom Service Level	>97%	Material/Part Performance	>98%

- Participation in measurement and strategy development and refinement by a wide cross-section of the organization,
- Identifying best practices and sharing across the organization,
- Using technology to facilitate data analysis and regular reporting, and
- Providing incentives to reach performance goals.

Meaningful measures should track to the strategic goals of the organization. Some measures are for senior managers to assess performance; others are more specific to particular business areas. Measures should encompass different perspectives to get a true picture of the organization's performance (e.g., financial, customer, or process). Some common performance measures are shown in Table H.1.

Capital Asset Management Enabling Technology

The adaptive integration of IT-enabled analytical capabilities affords an opportunity to get a collective view of the capital asset inventory and attribute data, as well as its capital asset measured performance within the context of organizational goals, from individual facilities to the entire enterprise's portfolio. This integrative capital asset planning and management capability provides visibility to the information, enabling a better understanding of the facility's capital asset's current performance capability and short- and long-term life cycle costs. It further provides information that can be used to determine user-introduced funding scenario impacts and create multiyear capital investment plans and budgets based on requirements, funding expectations, or both. The resulting enterprise-wide data analysis and decision-making capability will empower facility professionals to confidently perform the gap analysis used to advocate for investment program funding required for making changes to the organization's facility capital asset portfolio, based on near- and long-term mission (or business) priorities. Data-driven, informed determinations should provide the organizational leadership with confident program investment recommendations that will maximize facilities capital asset performance and value, as critical enablers of organizational business operations.

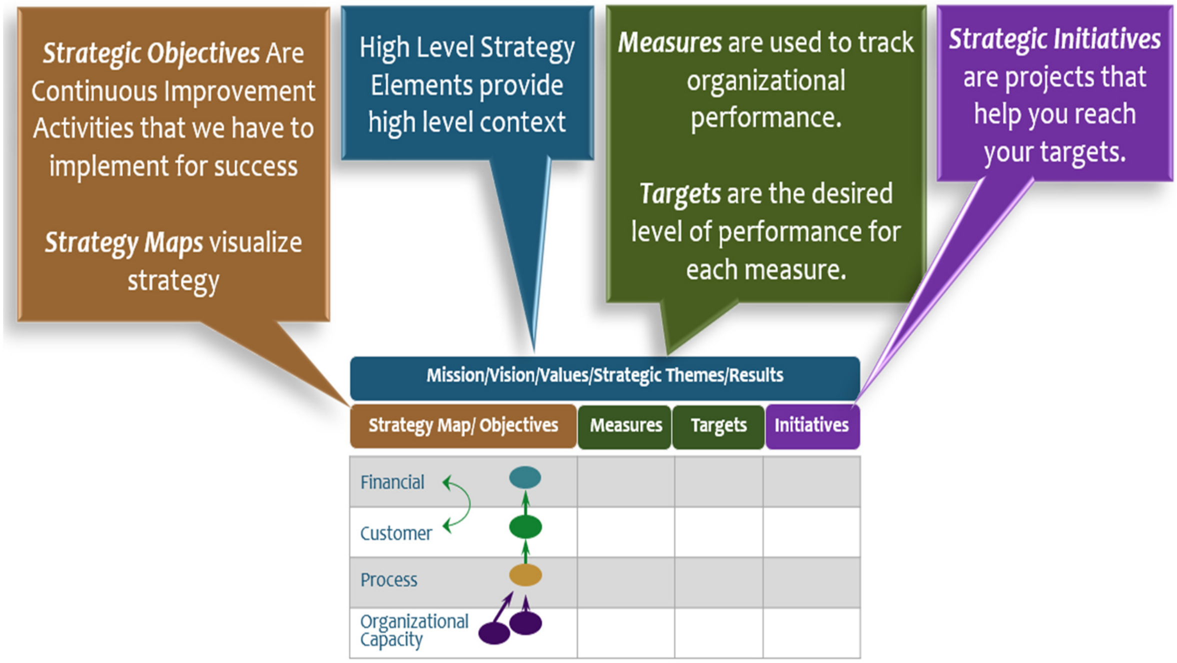


FIGURE H.2 Balanced Scorecard SOURCE: Reprinted with permission from Balanced Scorecard Institute, a Strategy Management Group Company. Copyright 1997 -2019.

Employing a Balanced Scorecard (BSC) framework could help NIH to comprehensively translate its strategic objectives into coherent sets of performance metrics used to provide feedback on resulting activity outcomes.

Recognizing core facilities are key elements in the research portfolio of academic and private research institutions, a study performed to promote and encourage the use of assessment tools used for evaluating the need and effectiveness of core facilities performance, with respect to the strategic planning process. The results determined that the need for strategic planning, as an enabler of core facility performance, is driven by two factors: (1) aligning institutional strategic goals with investment in core facilities and (2) ensuring that this investment is sustainable (Turpen et al., 2016).

Adopted by 50 percent of Fortune 1000 companies in North America in addition to 40 percent of companies in Europe employing a variant (Yu et al., 2009), the BSC system translates an organization's strategy into action, and becomes a key input used in aligning facility management strategy to organizational strategy. The system connects the dots between big picture strategy elements such as mission (our purpose), vision (what we aspire for), core values (what we believe in), strategic focus areas (themes, results and/or goals) and the more operational elements such as objectives (continuous improvement activities), measures (or key performance indicators, or KPIs, which track strategic performance), targets (our desired level of performance), and initiatives (projects that help you reach your targets).

The BSC provides the facility management staff with information on how the entire organization is performing. It is "balanced" because a well-developed BSC highlights a change that is often balanced by an opposite reaction elsewhere in the system. The entirety of the NIH corporate enterprise—comprised of institutes, centers, program offices, finance, facilities, and other support functions—can be viewed through the BSC perspective to develop metrics, collect data, and analyze options that can transform facility and real estate requirements identified in the strategic, master, or annual facility plans into outcomes with measurable performance outcomes. The BSC serves as a means of reporting to senior leaders and stakeholders how facility management supported the accomplishment of NIH goals and objectives. An illustration of the logic behind the BSC is shown in Figure H.2.

Conclusion

At one time, the best practices in capital asset management were limited to inclusion during design and construction phases of the facility life cycle, and the focus on performing effective preventative and corrective maintenance operations did not occur until after the newly acquired capital asset was commissioned into service. Over time, the understanding or capital asset management has grown to be very sophisticated (IWR, 2013).

Government and commercial businesses with substantial physical capital assets are developing capital asset management strategies to help them make critical decisions about when and where to invest, to optimize the life of their existing capital assets and to prioritize funding to handle present and future customer demands. Benefits derived for increased use and maturity include the following:

- Increase the efficiency and effectiveness of real property services.
- Reduce the cost of operations and maintenance.
- Increase facility end user satisfaction.
- Ensure that capital assets are better sustained for the long term.
- Ensure that the organizational missions are supported.
- Allow scarce resources to be distributed to those areas that have the greatest need.
- Mitigate potential risks of audit by oversight agencies.

The integration of the facility capital asset management principles and practices into the strategic planning process better enables making capital need decisions resulting in the efficient, effective, and economic delivery of facility and infrastructure capabilities to support organization goal obtainment. It also empowers FM leadership with the ability to answer core questions that address how best to manage facilities to achieve greater efficiency and effectiveness:

- What inventory of facilities and equipment does the organization control ("as-is" portfolio)?
- What is the condition of each facility and its related equipment?
- What level of funding is required to properly sustain the facilities and equipment portfolio over time?
- How does one determine when it is best to divest instead of continuing to invest in a facility?
- Which facilities and equipment projects are the highest priorities, and where should the organization focus resources?
- How should the organization monitor the performance of its capital assets over time and better integrate the budgeting process for these capital assets with their performance?

GUIDELINES AND PRACTICES

The International Facility Management Association (IFMA) published in their two most recent forecast reports that the top trend that facility professionals will face in the coming years is the greater importance placed in the need to link the role of facilities to an organization's core business strategies (IFMA, 2007, 2011). Studies completed by CFO Research Services and NACORE determined: (1) 20 percent of an organization's income statements are real estate and facilities expenses; (2) 35 percent of an organization's balance sheet capital assets are real estate and facilities; and (3) 48 percent of an organization's greenhouse gas emissions are produced by building (Sawhill, 2008; CFO Research and NACORE). Consequently, facilities are expected to increase in their recognition as a critical enabler of any organization's successful implementation of their strategic business plan. Additionally, physical facilities can have a large role in determining productivity and supporting innovation, efficiency, employee satisfaction, and public perception of an organization (IFMA, 2007). Whether owned or leased, an organization's real property portfolio of facilities and associated infrastructure are the results of past decisions that presently help or hinder an organization's ability to achieve its desired future state.

For facility management organizations, the most strategic issue is how to align the FM organization's strategy to the entire organization's strategy. In other words, the end goal of the facility strategic planning process is to develop comprehensive plans proposing how the entire portfolio of current and future facilities serves as critical enablers directly supporting the accomplishment of corporate and business unit goals and objectives. At the beginning of this century, the U.S. Air Force (USAF) corporate leadership recognized that they could no longer spend significantly decreased and limited funding to maintain a physical plant capacity not needed for mission success. This and many other important factors, such as increasing energy costs, a significantly decreased level of installation support funding, new organizational constructs, and changes in information technology systems drove new ways of thinking (Eulberg, 2008).

As the USAF, along with the entire Department of Defense (DoD), underwent a protracted period of transition during the past decade, the Air Force Office of the Civil Engineer—the corporate-level facility management organization for the USAF—developed strategic planning documents that outlined (1) the strategic context driving the needs for change; (2) an affirmation of their functional mission, as carried about by over 56,000 personnel operating at 166 Air Force installations around the world; (3) a shared vision to provide combat support enabling the projection of global air, space and cyber power; and (4) the new civil engineer (FM) goals, and associated objectives, each developed based on an understanding of the USAF's new strategy and critical priorities. However, arguably most importantly, the USAF's strategic facility plan's provided the business case supporting how they expected to plan, prioritize, and allocate USAF-provided resources used to "build sustainable installations" (streamline facility and infrastructure capital assets while optimizing operational capabilities) by including a matrix depicting how the civil engineer goal and objectives to align with the Air Force's new priorities.

Similarly, NIH's facility master planning protocol recognizes the need to provide an update of the blueprint developed in 2013 to ensure that funded capital investments are consistent with the long-term vision of the organization. Although not specifically addressed, the more recently released NIH-wide Strategic Plan from 2016-2020 and the Strategic Plan for Data Science Plan does allude to the high-level need to address the current and future real estate support requirements to enable the accomplishment of their respective goals. A strategic facility plan reflects the input from the corporate organization and all major business units and end users to show that it was developed from a systemwide perspective. Defined in relation to the entire organization's and the facility management organization's mission and vision, the strategic facility planning goals and objectives demonstrate affordable, feasible, and approved proposals that translate the organization's strategic objectives into tangible facility response propositions.

Observation: To improve long-term planning decision making results, performance metrics can be used during the evaluation process to determine how well an organization is achieving its stated goals and objective.

THE ROLE OF PERFORMANCE MEASURES

Many organizations now include facilities issues in their executive committee and business planning discussion. Some measure the impact of facilities on workforce productivity and business performance, while others view the quality of their facilities as an important contributor to the corporate brand, and to attracting and retaining talent (RICS, 2012). Regardless of the basis for doing so, the measurement of performance is a critical first step that leads to controlling performance and eventually improving performance. If you cannot measure something, then you cannot understand it. If you cannot understand it, then you cannot control it. If you cannot control it, then you cannot improve upon it.

The most useful strategic plans are succinct and easily translated into useful measures that denote how well an organization has accomplished predetermined objectives that achieve desired performance outcomes (Schilder, 2013). NIH has made considerable investment in the development of corporate-wide and the business unit strategic plans from the institutes, centers, and program offices to capitalize on new opportunities for research explorations, while leveraging advance information and medical science technologies, to achieve each respective desired future state that brings value to its customers, stakeholders, and the nation. With the strategic goals and objectives identified, coupled with the stated recognition of the need to evaluate their effectiveness, candidate strategic and operational measures should be identified based on those realistic and quantifiable objectives. These objectives also help to shape the lower-level metrics and KPIs that will become part of their measurable strategy.

The FWG provides advisory support to the NIH Director, IC leadership, and the Steering Committee on matters pertaining to the planning, acquisition, development, and use of land and facilities for the pursuit of NIH mission. According to the FWG Charter, this responsibility includes developing long-range master plans, capital facility plans coupled with proposing capital and operating budget investments for chief decision maker approval. These decisions should be based on the organization's anticipated performance against key operational performance targets. The performance drivers—a set of leading indicators used to show how an organization achieves a given outcome—and the key performance indicators (KPIs)—quantifiable metrics reflecting how well an organization is achieving its stated goals and objectives—provide the emphasis for strategic and operational improvement, create an analytical basis for decision making, focus attention on what matters most, and can be used to report progress against an implementation outcome expectation reflected in a Strategic or Master Plan.

A technical report produced by the National Research Council (NRC, 2004), working in conjunction with the Federal Facilities Council, contends that it is important that agencies track (1) performance measures that characterize their facilities portfolios; (2) the level of alignment of their portfolios with their organizational missions; (3) investment levels; and (4) the results or outcomes of their investments. Portfolio-oriented performance indicators should be established to improve decision-making about facilities investments and to improve management of federal facilities portfolios. Performance measures aligned with strategic and operational facility planning objectives developed in support of achieving NIH corporate organizational or subordinate business unit objectives provide a better return on investment results.

I

Capital Asset Portfolio Performance-Based Capital Planning Decision Making

CAPITAL ASSET INVENTORY AND CONDITION ASSESSMENT

After receiving the strategic planning inputs of the organizational priorities, capital asset space allocation requirement, and available financial resources, organizations conduct an inventory of all facilities and supporting infrastructure capital assets—the Bethesda Campus portfolio in the case of the National Institutes of Health (NIH). An inventory typically includes multiple building components, such as building foundation and structural elements; plumbing, mechanical, irrigation, and electrical systems; building envelope and roofing systems; and hazardous materials. Establishing and continuing a regular ongoing inventory of facility capital assets—as has been conducted by the NIH Office of Research Facilities (ORF)—provides the foundation for effective capital planning.[1]

Once the capital asset inventory baseline has been documented, assessments are conducted to determine the facility and equipment condition, typically through a life cycle condition assessment that is based on a Facility Condition Index (FCI).[2] A life cycle condition assessment captures the year of last replacement for major facility components and equipment. The manufacturer's estimated design life for each individual system is then applied to the year of last replacement to project future or "outyear" requirements. This method is combined with the subject matter expert opinion of facilities professionals to produce a reliable, cost-effective method used to establish a baseline condition of the capital asset portfolio. As part of the capital asset condition assessment, data to track remaining useful life, primary failure modes, and failure triggers is also typically identified (Hirai et al., 2004).

[1] Bill East, U.S. Army Corps of Engineers, Engineer Research and Development Center, "Obtaining and Maintaining Accurate Asset Inventories," November 13, http://sites.nationalacademies.org/cs/groups/depssite/documents/webpage/deps_085867.pdf

[2] FCI, Deferred Maintenance divided by Current Replacement Value. Deferred Maintenance refers to the existing maintenance backlog, while Current Replacement Values for constructed facilities are determined by estimating the cost to replace the existing facility with an identical one.

To determine optimal capital asset condition level by capital asset, best practices suggest the critical importance of establishing a link between capital asset condition level and the impact with respect to enabling the accomplishment of end user mission/business objectives. The condition of the built-environment components is one means to optimizing operational and strategic business performance. Working together with scientists, staff, and facilities professionals to determine specific critical performance requirements in the campus built environment is critical in determining how administrative, office, clinical, and laboratory research performance requirements can be sustained and enhanced.

CAPITAL ASSET PRIORITY INDEX

By combining capital asset condition and organizational mission, NIH organization leadership, based on the advice and recommendation from the Facilities Working Group (FWG), have the opportunity to identify strategic capital asset portfolio opportunities using, for example, a Capital Asset Priority Index (API).

API is a quantitative metric, currently used by NASA (Lipka, 2016) and the National Park Service (NPS) to assess the priority, or level of importance, of facilities relative to one another. API is one tool that facility managers can employ (in conjunction with other key metrics such as utilization, condition, and operating costs) to support policy-level strategic capital investment decision making. It enhances the ability of managers to make the best decisions possible to determine which capital assets to repair, where and when to build new, whether to enter or exit leases, and when to dispose of capital assets, all within the context of contribution to mission (DOI, 2005).

API is recognized by the Federal Real Property Council as a valid approach to comply with its “Mission Dependency” data requirements (LeMay and Armstrong, 2009). Furthermore, API has been recognized as a best practice and adopted by ASTM as a Standard (ASTM E-2495).

By combining API and FCI, organizational leadership can identify key and surplus capital assets:

- The high API-high FCI area (top-right quadrant) contains key capital assets that should receive increased management attention and/or additional investment.
- The low API-low FCI area (bottom-left quadrant) should receive less operation and maintenance (O&M) budget and should be assessed for potential transfer to where API can be increased.
- Capital assets in the low API-high FCI area (bottom-right quadrant) should be divested.

Regardless of the specific data system utilized, the ability to more accurately prioritize capital assets based on capital asset condition and research program priorities (mission support) enables NIH senior leadership to align funding and to allocate resources for the most valued capital assets on the NIH Bethesda Campus. In addition, senior leadership will have the opportunity to more rigorously assess the comparative value of capital budget investments specific to strategic research program decisions.

SUMMARY

At one time, the best practices in capital asset management were limited to inclusion during design and construction phases of the facility life cycle, and the focus on performing effective preventative and corrective maintenance operations did not occur until after the newly acquired capital asset was commissioned into service. Over time, the understanding or capital asset management has grown to be very sophisticated (IWR, 2013).

The integration of the facility capital asset management principles and practices into the strategic planning process better enables making capital need decisions resulting in the efficient, effective, and economic delivery of facility and infrastructure capabilities to support organization goal obtainment. They also empower facilities management leadership with the ability to answer core questions that address how best to manage facilities to achieve greater efficiency and effectiveness:

- What inventory of facilities and equipment does the organization control ("as-is" portfolio)?
- What is the condition of each facility and its related equipment?
- What level of funding is required to properly sustain the facilities and equipment portfolio over time?
- How does one determine when it is best to divest instead of continuing to invest in a facility?
- Which facilities and equipment projects are the highest priorities, and where should the organization focus resources?
- How should the organization monitor the performance of its capital assets over time and had better integrate the budgeting process for these capital assets with their performance?

J

Glossary

Biomedical research—Research that is conducted to increase fundamental knowledge and understanding of the physical, chemical, and functional mechanisms of human life processes and diseases.

Built environment—The built environment includes society's physical infrastructure and integrated systems that create the conditions for sustained health, prosperity, and social well-being.[1]

Capital budget—The result of carefully coordinated institutional capital planning and budgeting processes for effective infrastructure and capital asset management. The budget represents the process used for identifying needs, determining appropriate service levels, and prioritizing individual capital projects.[2] The impact of the annual capital budget on the operating budget as well as potential or confirmed funding sources is also identified in the capital budget.

Capital Facilities Master Plan—The plan represents the comprehensive multiyear (5-, 10-, or 20-year) institutional building, site, and infrastructure facilities needs integrated within the fabric of a campus and aligned with the institution's strategic vision—all to ensure effective management of capital assets. The plan serves as one of several tools used to inform capital budget development processes and assist annual institutional capital investment prioritization.[3]

Capital improvement—A change or an addition to an asset that improves its performance or appearance or extends its useful life.

---

[1] See the Arizona State University's School of Sustainable Engineering and the Built Environment website at https://ssebe.engineering.asu.edu/, accessed February 17, 2019.

[2] See Government Finance Officers Association, http://www.gfoa.org/capital-budgeting-infrastructure-finance-june-2018, accessed February 17, 2019.

[3] See Government Finance Officers Association website at http://www.gfoa.org/capital-improvement-planning-budgeting-resource-center, accessed February 17, 2019.

Capital planning—An integral part of an institution's strategic planning process that involves the process of analyzing, giving priority to, and allocating funds for the major construction and maintenance of infrastructure in a given community. Capital planning leads to the development of a capital plan.[4]

Clinical research—Clinical research aims to advance medical knowledge by studying people, either through direct interaction or through the collection and analysis of blood, tissues, or other samples.

Condition assessment—Periodic inspection by qualified personnel to determine and document the functional condition of a capital asset and identify maintenance, renewal, or replacement requirements of the asset evaluated.

Condition Index (CI)—CI is a calculated indicator of the depleted value of a constructed asset. Quantitatively, CI is one minus the ratio of accumulated Deferred Maintenance (DM) to the Current Replace Value (CRV) for a constructed asset times 100 (i.e., $[1 - DM/CRV] \times 100$).

Current Replacement Value (CRV)—The standard industry cost and engineering estimate of materials, supplies, and labor required to replace a facility or item of equipment at existing size and functional capability. This includes current costs for overhead, planning/design, construction, and construction management. Alternatively, it is the standard estimate for a government-purchased replacement of like capability. Replacement cost may also be estimated by accounting methods that inflate the original cost and costs of any subsequent capital improvements to current year using established price indices. Historic structures and inherited facilities (with zero acquisition costs) pose unique problems for estimating replacement costs.[5]

Facility Capital Planning and Management Program—A continuous systematic approach to identifying, assessing, prioritizing, and maintaining the specific maintenance, repair, renewal, and replacement requirements for all facility assets to provide valid documentation, reporting mechanisms, and capital cost information in a detailed database of facility issues.

Gross square footage—The total square footage in a building for all floors from the outside face of exterior walls, disregarding such architectural projections as cornices, buttresses, and roof overhangs. Gross area includes all research and administrative space, retail space, and other areas such as mechanical rooms, vending machine space, and storage. Gross area also includes major vertical penetrations such as shafts, elevators, stairs, or atrium space. This figure is used in defining construction costs for facilities.

Infrastructure—The necessary components that allow an entity to function. These items may include potable water, irrigation water, power, sanitary and storm sewers, and roadways and walkways.

Institutes and centers (of NIH)—NIH is made up of 27 institutes and centers (ICs), each with a specific research agenda, often focusing on particular diseases or body systems.

International Organization for Standardization (ISO)—International standard-setting body that promotes worldwide, proprietary, industrial, and commercial standards.

Long-Range Physical Development Plan—A Long-Range Development Plan (LRDP) is a comprehensive plan that guides physical development such as the location of buildings, open space, circulation, and other land uses. An LRDP is intended to comprehensively identify the physical development required to achieve strategic institutional goals and objectives.

Maintenance—Maintenance is defined as the recurring annualized costs for planned activities needed to maintain an asset's functionality and capacity over its expected life. This includes but is not limited to planned and scheduled activities such as inspections, preventive maintenance, refinishing, painting, weatherproofing, and parts replacement.

---

[4] National Academies of Sciences, Engineering, and Medicine, 2017, *Strengthening the Disaster Resilience of the Academic Biomedical Research Community: Protecting the Nation's Investment*, The National Academies Press, Washington, D.C.

[5] The General Services Administration defines the term as follows: "Replacement Value is defined as the cost required to design, acquire and construct an asset to replace an existing asset of the same functionality, size, and in the same location using current costs, building codes, and standards."

Maintenance backlog—A comprehensive summary of building and infrastructure system maintenance that was not performed as required or recommended and was deferred to a future time.

Net assignable square footage—The area of a floor suite of rooms that is suitable for occupancy including secondary corridors. It excludes common or shared space that cannot be reasonably assigned for program purposes such as main egress corridors, hazardous waste marshaling areas on the loading dock, and other nonprogrammable space.

Renovation—The improvement, addition, or expansion of facilities by work performed to change the interior alignment of space or the physical characteristics of an existing facility so that it can be used more effectively, be adapted for new use, or comply with building-specific and building-related regulatory codes and requirements. Includes the total expenditures required to meet evolving technological, programmatic, or regulatory requirements.

Repairs—Work that is performed to return building or infrastructure systems and related equipment to service after a failure or to make its operation more efficient. The work restores a facility or component thereof to such condition that it may be effectively utilized for its designated purposes by overhauling, reprocessing, or replacing constituent parts or materials that have deteriorated by action of the elements or usage and have not been corrected through maintenance.

Research enterprise—An entity that defines the policies, procedures, organizational structure, staffing, facilities, and practices used to fulfill an academic institution's research mission.

Usable square footage—The secured area (square footage) occupied exclusively by the tenant within the tenant's leased space. The usable area times the load factor for common area results in rentable area on which rent is charged. Usable area can be measured in many ways, but the most common measurement for office buildings is according to Building Owners and Managers Association (BOMA) standards. It does not include restrooms, elevator shafts, fire escapes, stairwells, electrical and mechanical rooms, janitorial rooms, elevator lobbies, or public corridors (for example, a corridor leading from the elevator lobby to the entrance of a tenant's office).

SOURCE: U.S. Department of State, n.d.. *Guide to Green Embassies: Eco-Diplomacy in Operation*, https://overseasbuildings.state.gov/green_guide, accessed February 14, 2019. University of California, Office of the President, n.d., "Construction Services: UC Facilities Manual," https://www.ucop.edu/construction-services/facilities-manual/index.html, accessed February 14, 2019. Federal Accounting Standards Advisory Board, 2018, *FASAB Handbook of Federal Accounting Standards and Other Pronouncements, as Amended as of June 30, 2018: FASAB Handbook, Version 17.* APPA, n.d., "APPA Glossary," https://www.appa.org/research/glossary.cfm. National Institute for Child Health and Human Development, n.d., "Clinical Research," https://www.nichd.nih.gov/health/clinical-research. National Library of Medicine, n.d., "Biomedical Research," https://www.nlm.nih.gov/tsd/acquisitions/cdm/subjects16.html. Federal Real Property Council, 2018, *2018 Guidance for Real Property Inventory Reporting,* General Services Administration, Washington, D.C., June 12. NIH Design Requirements Manual (Issuance Notice 12/12/2016) Rev. 1.4: 4/24/2019.

K

Acronyms

ACD	Advisory Committee to the Director
ACRF	Ambulatory Clinical Research Facility
ARRA	American Recovery and Reinvestment Act
ARS	USDA Agricultural Research Service
ASPR	Assistant Secretary for Preparedness and Response
B&F	Buildings and Facilities
BARDA	Biomedical Advanced Research and Development Authority
BC	Bethesda Campus
BMAR	Backlog of Maintenance and Repair
BSC	Balanced Scorecard
CC	Clinical Center
CCWG	Clinical Center Working Group
CDC	Centers for Disease Control and Prevention
CDR	Center for Disease Research
CI	Condition Index
CISIP	Condition Index, Sustainment, and Improvement Funding Needs Plan
CIT	Center for Information Technology
CIT	communications and information technology
CORBEL	Coordinated Research Infrastructures Building Enduring Life-Science Services
CRC	Clinical Research Center
CREx	Collaborative Research Exchange
CRV	Current Replacement Value
CSR	Center for Scientific Review
CUP	Central Utility Plant
Cx	commissioning
DFOM	Division of Facilities, Operations, and Maintenance

DFP	Division of Facilities Planning
DHS	Department of Homeland Security
DoD	Department of Defense
DOE	Department of Energy
DRM	Design Requirements Manual
DTR	Division of Technical Resources
DVR	Division of Veterinary Resources
EIS	Executive Information System
EO	executive officer
F&I	facilities and infrastructure
FAES	Foundation for Advanced Education in the Sciences
FDA	Food and Drug Administration
FEMP	Federal Energy Management Program
FIC	Fogarty International Center
FNIH	Foundation for the National Institutes of Health
FPAA	Facility Project Approval Agreement
FRV	Functional Replacement Value
FTE	full-time equivalent
FWG	Facilities Working Group
FY	fiscal year
GAO	Government Accountability Office
GSA	General Services Administration
HHS	Department of Health and Human Services
HPC	high-performance computing
ICs	institutes and centers
IDA	Institute for Defense Analyses
IPD	Intramural Professional Designation
IRP	Intramural Research Program
IRTA/CRTA	Intramural Research Training Award, denominated CRTA at NCI
LCCA	Life Cycle Cost Analysis
LSP	Lease Space Plan
MDI	Mission Dependency Index
MRI	magnetic resonance imaging
NASA	National Aeronautics and Space Administration
NASEM	National Academies of Sciences, Engineering, and Medicine
NASF	net assignable square feet
NCATS	National Center for Advancing Translational Sciences
NCCIH	National Center for Complementary and Integrative Health
NCI	National Cancer Institute
NCPC	National Capital Planning Commission
NEF	nonrecurring expense fund
NEI	National Eye Institute
NHGRI	National Human Genome Research Institute
NHLBI	National Heart, Lung, and Blood Institute
NIA	National Institute on Aging
NIAAA	National Institute on Alcohol Abuse and Alcoholism

NIAID	National Institute of Allergy and Infectious Diseases
NIAMS	National Institute of Arthritis and Musculoskeletal and Skin Diseases
NIBIB	National Institute of Biomedical Imaging and Bioengineering
NICHD	Eunice Kennedy Shriver National Institute of Child Health and Human Development
NIDA	National Institute on Drug Abuse
NIDCD	National Institute on Deafness and Other Communication Disorders
NIDCR	National Institute of Dental and Craniofacial Research
NIDDK	National Institute of Diabetes and Digestive and Kidney Diseases
NIEHS	National Institute of Environmental Health Sciences
NIGMS	National Institute of General Medical Sciences
NIH	National Institutes of Health
NIH-BC	National Institutes of Health-Bethesda Campus
NIMH	National Institute of Mental Health
NIMHD	National Institute on Minority Health and Health Disparities
NINDS	National Institute of Neurological Disorders and Stroke
NINR	National Institute of Nursing Research
NIST	National Institute of Standards and Technology
NLM	National Library of Medicine
NPS	National Park Service
NRC	National Research Council
NRL	Naval Research Laboratory
OD	Office of the Director
OIR	Office of Intramural Research
OITE	Office of Intramural Training and Education
OMB	Office of Management and Budget
OPDIV	Operating Division
ORF	Office of Research Facilities
ORS	Office of Research Services
PCT	Project Contract Team
PHEMCE	Public Health Emergency Medical Countermeasures Enterprise
PHI	personal health information
PI	principal investigator
POR	program of requirements
PNRC	Porter Neuroscience Research Center
R&D	research and development
RFAC	Research Facilities Advisory Committee
RI	research infrastructure
RML	Rocky Mountain Laboratory
SD	scientific director
SF	Square Feet
SFP	Space Facilities Plan
SRB	Space Recommendation Board
UARC	university-affiliated research center
USDA	U.S. Department of Agriculture
VA	Veterans Affairs
WDBG	Whole Building Design Guide