Rethinking the Components, Coordination, and Management of the U.S. Environmental Protection Agency Laboratories

ISBN
978-0-309-31237-0

118 pages
8.5 x 11
PAPERBACK (2014)

Committee on Strengthening the US Environmental Protection Agency Laboratory Enterprise: Phase 1â€”Priority Needs, Guiding Principles, and Overall Goals; Board on Environmental Studies and Toxicology; Division on Earth and Life Studies; National Research Council

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Committee on Strengthening the
US Environmental Protection Agency Laboratory Enterprise:
Phase 1—Priority Needs, Guiding Principles, and Overall Goals

Board on Environmental Studies and Toxicology

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

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This project was supported by Contract EP-C-09-003 between the National Academy of Sciences and the US Environmental Protection Agency. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the organizations or agencies that provided support for this project.

International Standard Book Number-13: 978-0-309-31237-0
International Standard Book Number-10: 0-309-31237-X

Additional copies of this report 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; Internet, http://www.nap.edu/.

Printed in the United States of America.

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Preface

The US Environmental Protection Agency (EPA) is undertaking an integrated evaluation of its laboratories to strengthen the management, effectiveness, and efficiency of its laboratory network and to enhance its capabilities for research and other laboratory-based scientific and technical activities.[2] EPA is collecting and analyzing data on the operating costs, workforce, facilities, and science contributions of its laboratory facilities. The evaluation is also intended to address US Government Accountability Office (GAO) recommendations that EPA improve cohesion in managing and operating agency laboratories and to help the EPA laboratory enterprise respond to change and be equipped to handle emerging scientific challenges.

As part of its effort, EPA sought independent expert advice from the National Research Council. In response, the National Research Council established the Committee on Strengthening the US Environmental Protection Agency Laboratory Enterprise: Phase 1—Priority Needs, Guiding Principles, And Overall Goals. The statement of task, developed in consultation with EPA, served as a guide for the committee's work. The committee was asked to assess EPA's highest-priority needs for mission-relevant laboratory science and technical support, to develop principles for the efficient and effective management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals, and to develop guidance for enhancing efficiency and effectiveness now and during the next 10 years. It was asked not to assess the organization, the facility-level and portfolio-level master plans, or the consolidation initiatives related to EPA's laboratory enterprise, because such analysis is being undertaken in a separate effort.

The National Research Council assembled a committee of 14 members who had expertise in executive management and experience with multifacility laboratory organizations; environmental sciences; exposure science; health risk assessment; toxicology; environmental medicine; ecosystem services; ecologic risk assessment; environmental law, policy, regulation, and risk management; and environmental program design and management. The committee included members knowledgeable about the different types of EPA laboratories and their functions and contributions, relevant activities of other federal and state government and academic laboratories, and the nexus between laboratory science and decisions about risk assessment, protective human health and environmental standards, risk-management decisions, and regulations and EPA statutory requirements. We are grateful to the members of the committee for their efforts throughout this study.

In the course of preparing its report, the committee held public information-gathering sessions during four of its meetings. In addition to the information from those presentations, the committee requested written materials to describe the structure, function, and management of the EPA laboratories. Dale Pahl (EPA) coordinated the submission of extensive written materials in response to our request. We gratefully acknowledge the efforts made by those involved in providing us with that information.

In carrying out its task, the committee built on relevant previous reports of the National Research Council, GAO, and the EPA Science Advisory Board and Board of Scientific Counselors. The committee relied on its collective judgment and experience in identifying applicable aspects of the earlier reports in developing its principles and recommendations.

[2] R. Perciasepe, US Environmental Protection Agency, presentation to the committee, September 17, 2013.

This report has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the National Research Council Report Review Committee. The purposes of the independent review are to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of 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 for their review of this report: David A. Dzombak, Carnegie Mellon University; William H. Farland, Colorado State University, retired; W. Michael McCabe, McCabe & Associates; Mary D. Nichols, California Air Resources Board; Gordon H. Orians, University of Washington; Joel M. Schur, George Mason University; Martyn T. Smith, University of California at Berkeley; and John C. Wall, Cummins, Inc.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of the report was overseen by the review coordinator, Edwin H. Clark II, Earth Policy Institute, and the review monitor, Lawrence T. Papay, Science Applications International Corporation, retired. Appointed by the National Research Council, they were responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of the report rests entirely with the committee and the institution.

The committee is grateful for the assistance of the National Research Council staff in preparing this report. Staff members who contributed to the effort are Raymond Wassel, project director; James Reisa, director of the Board on Environmental Studies and Toxicology; Mark Lange, program officer; Kara Laney, program officer; Constance Karras, research associate; Keri Stoever, research associate; Norman Grossblatt, senior editor; Mirsada Karalic-Loncarevic, manager of the Technical Information Center; Radiah Rose, manager of editorial projects; Ricardo Payne, program coordinator; and Orin Luke, senior program assistant.

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and
Jonathan Z. Cannon, *Vice Chair*
Committee on Strengthening the US Environmental Protection Agency
Laboratory Enterprise: Phase 1—Priority Needs, Guiding Principles,
and Overall Goals

Abbreviations

ARPA-E	Department of Energy's Advanced Research Projects Agency – Energy
BOSC	EPA Board of Scientific Counselors
CMAQ	community multiscale air quality
DARPA	Department of Defense's Defense Advanced Research Projects Agency
E-ARPA	Environmental Advanced Research Projects Alliance
EPA	US Environmental Protection Agency
ERLN	Emergency Response Laboratory Network
GAO	US Government Accountability Office
GPRA	Government Performance and Results Act
GRO	EPA's Greater Research Opportunities fellowships
NEIC	EPA National Enforcement Investigations Center
NERL	EPA ORD National Exposure Research Laboratory
NHEERL	EPA National Health and Environmental Effects Research Laboratory
NRMRL	EPA ORD National Risk Management Research Laboratory
NVFEL	National Vehicle & Fuel Emissions Laboratory
OAR	EPA Office of Air and Radiation
OCSPP	EPA Office of Chemical Safety and Pollution Prevention
OECA	EPA Office of Enforcement and Compliance Assurance
ORD	EPA Office of Research and Development
OSWER	EPA Office of Solid Waste and Emergency Response
SAB	EPA Science Advisory Board
STAR	Science To Achieve Results
VERA	voluntary early retirement authority
VSIP	voluntary separation incentive payment

Contents

RETHINKING THE COMPONENTS, COORDINATION, AND MANAGEMENT OF THE U.S. Environmental Protection Agency Laboratories

Summary

As an agency with the mission and regulatory responsibility to protect human health and the environment, the US Environmental Protection Agency (EPA) necessarily relies on science as an integral part of its activities. The agency's responsibility for regulation and enforcement creates a unique combination of drivers for obtaining scientific information to provide fundamental knowledge to inform policy and rules; for establishing robust and defensible analytic methods to support monitoring, certification, and compliance; and for continually innovating to respond to new environmental agents of concern, forensic needs, terrorism, and natural disasters.

EPA applies scientific results that have been provided by various parts of its own organization and by external organizations. The agency clearly requires substantial high-quality inhouse scientific expertise and laboratory capabilities so that it can answer questions related to regulation, enforcement, and environmental effects of specific chemicals, activities, and processes. It is also usually faced with situations in which research or analytic work is time-critical, so it maintains dedicated laboratory staff and facilities that can respond quickly to such needs.

In recent years, EPA has made several changes to improve the efficiency and effectiveness of its laboratories, such as the designation of national program directors to align the work of research laboratories with the needs of the agency's regulatory program offices. The agency is currently undertaking an integrated evaluation of its laboratories to enhance the management, effectiveness, and efficiency of its laboratory enterprise[1] and to enhance its capabilities for research and other laboratory-based scientific and technical activities. The results of EPA's evaluation may include options for colocation and consolidation of laboratory facilities.

THE NATIONAL RESEARCH COUNCIL COMMITTEE'S STUDY

As part of its integrated effort, EPA asked the National Research Council to form a committee to assess the agency's highest-priority needs for mission-relevant laboratory science and technical support, to develop principles for the efficient and effective management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals, and to develop guidance for enhancing efficiency and effectiveness now and during the next 10 years.[2] The committee was not asked to identify the highest-priority needs anew, but to assess needs identified previously and to develop principles that would help EPA meet its scientific obligations over the next 10 years.[3] Also, it was asked not to assess the physical space and configuration options of EPA laboratories, because that analysis is being undertaken in a separate effort. EPA indicated that it will consider the findings, principles, and recommendations provided by this committee in developing an implementation plan for the laboratory enterprise. This is the committee's report.

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[1]"The EPA laboratory enterprise is the aggregate capability and capacity required by its laboratories and laboratory-based centers to meet the Agency's high-priority mission needs of its programs and strategic goals" (G. Paulson, US EPA, presentation to the committee, September 17, 2013).

[2]The full statement of task is presented in Appendix A.

[3]EPA identifies highest-priority needs based on mission relevance, legislative mandates, and guidance from EPA's strategic plan, which is revised every 4 years. Also, the NRC report *Science for Environmental Protection: The Road Ahead* (NRC, 2012a) identified scientific priorities for the agency for the next 10 years.

THE ENVIRONMENTAL PROTECTION AGENCY LABORATORY ENTERPRISE

EPA's laboratory enterprise consists of a distributed network of three general types of laboratories that have different immediate priorities, are typically in different places, and are required to do different things.

- *Regional office laboratories* provide scientific data that support the needs of regional environmental programs for informing immediate and near-term decisions on environmental conditions, emergency response, compliance, and enforcement.
- *National program office laboratories* develop and provide specific programs that support decisions on regulations, compliance, and enforcement related to legislative mandates at a national level.
- O*ffice of Research and Development (ORD) laboratories* develop knowledge, assessments, and scientific tools that underpin decisions about EPA's regulatory standards, risk assessments, and risk-management decisions.

Although there are institutional links (for example the EPA science advisor) and important interactions among the various types of laboratories that make up the enterprise, they do not function as a single entity. Not only do the three types of laboratories do different types of work, but their work typically has different timeframes. ORD laboratories may undertake research over a period of 5 years or more, whereas a regional office laboratory might need an immediate answer for a site-cleanup decision and a program office laboratory may be engaged in technical projects on motor vehicle emissions that last for several years. The different kinds of laboratories need different kinds of scientific and technical expertise and approaches, and they report to different managers and policy officials.

Beyond descriptions of the laboratory enterprise as a general concept, the committee received little information from EPA to describe the operational characteristics of the laboratories at the enterprise level. Rather, EPA's responses to the committee's information requests generally focused on specific types of laboratories. On the basis of our examination and review, we have concluded that EPA does not have a comprehensive justification or organizing vision for its current laboratory enterprise. The committee identified various opportunities where EPA laboratories could become more effective and efficient through a rethinking of its system of laboratories from an enterprise perspective. The committee recommends specific actions which, if implemented systematically, could provide additional benefit relative to the current management and function of the agency's network of laboratories.

EPA should approach management of its laboratory enterprise not so much as separate types of laboratories but as a system of the various laboratory efforts in EPA in which science and technical support activities are undertaken to support and advance the agency's mission–in other words, as an organized composition of diverse components. ***(Recommendation 4-1)***

EPA should develop a vision for its laboratory enterprise that maintains the strengths of the individual components but provides synergy through systematic collaboration and communication throughout the agency. ***(Recommendation 4-2)***

There are several possibilities for structuring the systematic communication and collaboration, and thus implementing the vision of the laboratory enterprise, as discussed in this report. **The committee recommends that the means of implementing the vision for the laboratory enterprise be determined by the EPA administrator with a view to meeting the functional criteria set forth in this report for enhancing the efficiency and effectiveness of the enterprise. (Recommendation 4-11)**

To implement this vision, we are not recommending that the entire laboratory enterprise be directed or managed by a single person, nor are we recommending that it be operated as a single entity. Those approaches would not reflect a full awareness of the benefits derived from the three different types of EPA laboratories and their ability to contribute to the agency's mission in different ways. Instead, we envision that the enterprise would seek to preserve the strengths of the different types of laboratories but provide for more systematic communication and coordination among them. Existing lines of communication can be enhanced. Similarly, coordination of existing networks and processes can be enhanced.

ANALYTIC FRAMEWORKS

The committee developed an analytic framework for each type of laboratory and the entire enterprise to help EPA align its laboratory facilities, functions, and capabilities with the highest-priority scientific needs related to the agency's strategic goals, such as addressing climate change, improving air quality, and protecting America's waters. The output of the laboratories supports decisions about regulatory standards, policies, risk management, emergency response, compliance, and enforcement. The frameworks are also applicable for addressing persistent or future challenges expected over the next 10 years, such as the need for better knowledge of the environmental and human health risks of low-dose exposures to metals and organic chemicals.[4] Figure S-1 represents a framework for the entire laboratory enterprise. In developing the frameworks, the committee considered efficiency and effectiveness criteria to guide EPA's investment, planning, and implementing actions and to establish formal and systematic arrangements for communication and coordination. We encourage EPA to develop and strengthen its management processes by using the frameworks to enable the individual types of laboratories to perform better and to synchronize with each other.

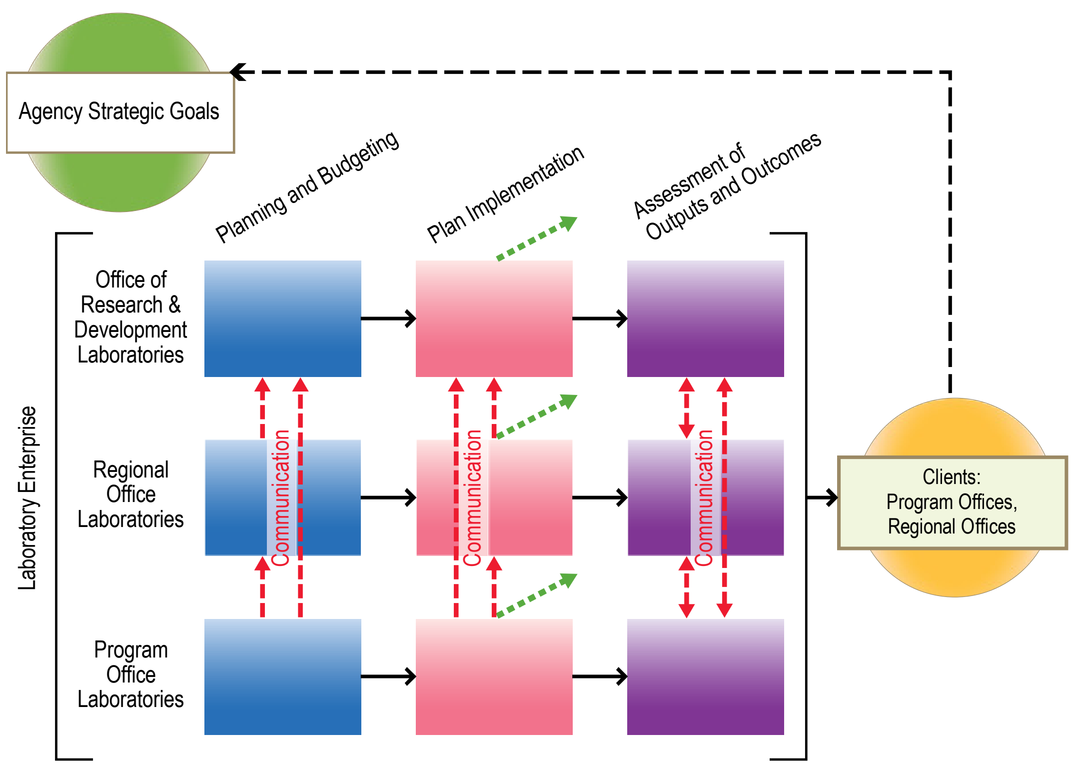

FIGURE S-1 The overall EPA laboratory enterprise, with an emphasis on lines and directions of communication that should be institutionalized. Other communication directions are not intended to be prohibited. In addition to communication, the dashed red lines represent coordination within the enterprise. The dotted green lines under "Implementation" indicate where EPA should reach outside the agency to other agencies, academe, and other research organizations to inquire about what is going on with respect to a given science need. Note: ORD = Environmental Protection Agency Office of Research and Development; PO = program office; RO = regional office.

[4]*Science for Environmental Protection: The Road Ahead* (NRC, 2012a) indicated that advances in analytic chemistry capabilities will continue to enable chemicals to be detected at ever lower concentrations in, for example, the blood of humans and in environmental media (air, water, and soil). This will give rise to questions about what the concentrations mean.

PRINCIPLES FOR EFFICIENT AND EFFECTIVE MANAGEMENT OF THE LABORATORY ENTERPRISE

The 2012 National Research Council report *Best Practices in Assessment of Research and Development Organizations* (NRC 2012b) provided a list of attributes that characterize an effective research and development (R&D) organization and are considered to be good indicators of the eventual impact and relevance of the organization and the R&D that it performs. Using those attributes, the present committee developed the following principles for the effective and efficient management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals:

1. Every science institution is more effective if it has a vision of how its scientists, technicians, and other professionals can best contribute to the organization's mission and goals.
2. Essential laboratory capabilities are the ones that are relevant to the current mission and the ones that anticipate future mission needs. Priorities for laboratory capabilities should focus on work that is central to the agency's mission rather than on small peripheral efforts.
3. Laboratories should avoid internal redundancy or duplication of capabilities that are readily available externally.
4. Recruiting, developing, and retaining an outstanding, committed scientific and technical workforce is crucial for maintaining outstanding laboratory capabilities.
5. State-of-the-art facilities and equipment are essential if a laboratory enterprise is to be able to meet current and future mission needs.
6. Effective management with appropriate flexibility enables an efficient and effective laboratory enterprise.
7. Communication and coordination among the laboratories within an organization are essential for efficiency and effectiveness.
8. Outstanding research and other science-related activities are the foundation for meeting current and future mission needs and for sustaining leadership in environmental science and applied research.
9. A strong linkage to universities, industry, research institutions, and other federal and state government organizations enhances the laboratory enterprise and prepares it for the future.

MANAGEMENT PROCESSES FOR THE LABORATORY ENTERPRISE

Various management processes could be strengthened to tie the components of the laboratory enterprise together and maintain the strengths of the individual types of laboratories without sacrificing the decided advantages that come from the in-depth experience, strong relationships, and proximity that have been the hallmark of laboratories that are dedicated to research, program offices, and regional offices. We looked specifically at planning and budgeting, plan implementation, assessment processes, and, perhaps most important, communication.

Planning

The committee commends EPA on its progress in aligning its research efforts with the needs of its regulatory program and regional offices and ultimately with its strategic goals through ORD's four-year strategic research planning process, which includes multiple reviews and outreach activities. However, it is possible that more can and should be done. Greater systematic involvement in the planning process by all of the agency's laboratories would probably yield a stronger and more efficient laboratory enterprise. At the very least, it would allow the various contributors to see how their efforts might connect to work done by others in moving toward its strategic goals. Greater systematic involvement of the laboratories in the planning process also would make it evident to EPA senior management where there are duplicative or overlapping resources that can be eliminated or redirected to other, more pressing needs of the agency. **EPA should ensure that its laboratory planning process includes cross–regional office and cross–**

program office laboratory input and that it is more transparent within the agency and to outsiders. *(Recommendation 4-3)*

Budgeting

In recognizing the need to move toward more efficient and more effective management of its laboratory enterprise, EPA may be hampered by a lack of critical budget information related to its laboratories. It appears that EPA does not currently assemble all the financial data needed to produce a budget for the entire laboratory enterprise. That may be in part because EPA has not traditionally viewed its laboratory systems as an overall enterprise and therefore has not considered it important to know how much was actually budgeted for the entire enterprise or for the individual laboratories wherever they are on an organization chart. However, if one views the laboratory enterprise as a system of various components that operate together at some level, such information could be valuable in enabling EPA to manage it.

Having such data would enable EPA not only to ensure that its available resources are being allocated to projects of the highest priority but also to make comparisons among laboratories. It would enable EPA to determine more easily the marginal cost of new laboratory capacity, equipment, or capabilities. It would enable EPA to determine more easily whether the budget provides for long-term laboratory needs, especially emerging issues, such as population growth and water and energy consumption. Equally important, it would enable *outsiders* to understand and evaluate the choices that EPA makes. Indeed, as resources become even more constrained and the scientific issues related to the environment become more complex and demanding, it may well be critical for EPA to have data to use in defending its need for resources if the laboratories are to carry out their functions. **EPA should conduct an annual internal accounting of the cost of the entire laboratory enterprise as a basis for assessing efficiency and assisting in planning.** ***(Recommendation 4-4)***

Funding Allocations

The committee observed that EPA does not have a process whereby the entire portfolio of laboratory projects can be arrayed to enable an evaluation of whether available funds are being allocated to activities in a manner that is best aligned with advancing the agency's mission. EPA should produce fairly accurate estimates of the costs of implementing various types of laboratory activities before undertaking projects and be able to provide final costs at the completion of projects. It can use such data to compare the costs of similar projects that are undertaken in different laboratories, to benchmark for outsourcing that is contemplated for similar kinds of projects, or to assess benefit:cost ratios for different kinds of projects undertaken in various laboratories. **EPA should compile adequate data regarding the costs of individual activities in the various laboratories so that it can manage the laboratory enterprise appropriately.** ***(Recommendation 4-6)***

Systematic Internal Collaboration

Collaborations among personnel in different components of EPA's laboratory enterprise currently appear to be mostly ad hoc rather than the result of a systematic process. The committee was encouraged to learn of various undertakings in EPA laboratories that illustrate approaches to efficient use of the capabilities of all its laboratories' personnel. Examples include the National Center for Computational Toxicology and the National Homeland Security Research Center. The approaches draw on the skills, expertise, and experience of the scientists, technicians, and engineers that work in the various types of laboratories. The committee commends EPA for developing these centers in the laboratory enterprise. **EPA should continue to look for innovative ways to address emerging problems and opportunities that create synergies among agency personnel who might encounter similar problems or opportunities within different EPA laboratories** within ORD, program offices, and regional offices**.** ***(Recommendation 4-5)***

Assessment

Most successful organizations use both internal and external mechanisms for assessment. It is important for managers to focus on such specific questions as, Are the results of sufficient quality to be useful? Do the research and other laboratory-based scientific and technical activities address the problem, and are the results ready for implementation? Does the work continue to reflect current program or compliance priorities?

Although the ORD planning process seeks internal comments on the relevance and utility of the outputs of the ORD laboratories, the committee understands that the program office and regional office laboratories do not undertake systematic internal assessments. **EPA's program office laboratories and regional office laboratories should undergo regular internal reviews of their efficiency and effectiveness. *(Recommendation 4-7)***

ORD not only has an internal assessment process but uses external reviews for assessment.[5] Requests for such external reviews are ad hoc, and there is no similar process for external review of the outputs of the program office and regional office laboratories. **EPA should expand the use of external reviews to cover all components of its laboratory enterprise. *(Recommendation 4-8)***

Communication

Communication is perhaps the most important aspect of laboratory management in that it facilitates coordination among the three types of laboratories within the enterprise. We recognize that there has been substantial progress in establishing and maintaining channels of communication throughout EPA and between ORD and the program offices and regional offices. For example, each regional office serves, on a rotating basis, as the lead regional office for designated responsibilities in EPA. In addition, we have seen several examples of various kinds of efforts at communication between program office and regional office laboratories, such as participation in weekly staff calls with the administrator's office. However, they do not appear to constitute systematic lines of communication among laboratories.

Communication is too important to be left to happenstance and informal arrangements. Difficult issues can arise as the components of the laboratory enterprise seek to coordinate their work. The challenge for EPA is to determine precisely what lines of communication are needed, which ones already exist, and which ones must be established. It should then clearly articulate the need for those lines. **EPA should determine precisely what lines of communication are needed, which ones already exist, and which ones should be established. It should then clearly articulate the need for these avenues and the mechanisms by which they will be sustained. *(Recommendation 4-9)***

WORKFORCE

The most reliable predictor of laboratory performance is the quality of the workforce. It is essential that the workforce be experienced and knowledgeable and that it possess creative scientific and technical capabilities. For a laboratory to be effective, it has to have employees with sufficient expertise for major projects that provide policy-relevant information or data to support regulatory action. The workforce should be nimble and adaptable to address new challenges. The current complexity and pace of the emergence of new challenges facing EPA, such as exposure to new chemicals and nanomaterials, makes the need for a highly capable workforce all the greater. Recruiting, developing, and retaining an outstanding, committed scientific and technical workforce are crucial for maintaining outstanding laboratory capabilities.

[5]In particular, the Board of Scientific Counselors, a committee convened under the Federal Advisory Committee Act, is charged with providing technical and management advice regarding ORD's research program and program plan development.

A critical issue facing EPA is the state of its scientific personnel. The number of full-time-equivalent laboratory staff has decreased over the last 15–20 years, and many senior scientists are approaching retirement age. EPA staff has been augmented by on-site contractors and postdoctoral associates, but there is a potential for loss of critical institutional knowledge as key staff members retire without hiring people to replace them and the time to transfer the senior staff members' knowledge to junior personnel. This concern applies throughout the laboratory enterprise, from regional laboratories to ORD research facilities.

Staffing high-quality scientists who have relevant expertise and who can embrace problems by drawing on information in many disciplines will require continued attention so that EPA can maintain and enhance its leadership in environmental science and technology. To "sustain leadership capabilities of its laboratory enterprise for environmental science and research", per this committee's Statement of Task, EPA will need individuals with excellent, high-quality expertise in science, engineering, and other related fields. To the extent practicable under budget constraints, three tools that would provide EPA flexibility in achieving continuing workforce excellence are the agency's training grant and fellowships programs, postdoctoral program, and Title 42 program**.** An important component of implementing each of these tools is periodic independent review to assess whether the efforts are meeting their intended objectives.

Training Grants and Fellowships

EPA is offering Greater Research Opportunities (GRO) undergraduate fellowships for environmental study. In the past, it has also offered Science to Achieve Results (STAR) graduate fellowships to support master's and doctoral candidates in environmental studies. However, STAR fellowships are not being offered in 2014. The potential transfer of the STAR graduate fellowship program to the National Science Foundation (NSF) illustrates a failure to recognize the differences in training between an EPA fellowship program focused on environmental science and technology and the NSF emphasis on the basic Earth-science or physical-science fellowship. **EPA should continue, enhance, and expand its student training grant programs, such as GRO. The STAR fellowship program should be reinstated in EPA to support research programs that are specific to EPA's mission and goals.** ***(Recommendation 3-5)***

Postdoctoral Program

By using the federal postdoctoral research program, EPA can hire early career scientists to address critical research problems. The program also provides postdoctoral scientists with a deeper understanding that may enhance their research futures, wherever their next professional positions may be. **EPA should continue its planned hiring of postdoctoral researchers by the Office of Research and Development (ORD) and expand it to other types of laboratories as appropriate.** ***(Recommendation 3-6)***

Title 42

EPA needs the highest-quality scientific and engineering expertise if it is to protect health and the environment effectively and efficiently, so it needs personnel tools to hire and attract the best and the brightest. The Title 42 program is one of the most important tools for EPA to use to achieve success.[6] Through Title 42, EPA can recruit and retain world-class scientists and engineers who can strengthen the agency's research and improve the application of science to address its regulatory responsibilities. In 2010, NRC reviewed EPA's use of temporary Title 42 authority and concluded that the program was

[6]Title 42 refers to an administrative provision in §209(f)–(h) of the *US Code* that gives federal agencies the authority to appoint highly qualified consultants, scientists, and engineers at a pay scale outside civil-service laws described under Title 5. Through the Title 42 hiring program, federal agencies can compete with industry and academe to fill critical senior-level positions.

working well, hiring and retaining top scientists that helped the agency achieve its mission.[7] It recommended that permanent Title 42 authority be granted to EPA and the number of Title 42 positions at EPA be expanded on the basis of program needs and available budget.

In the FY 2014 appropriation, Congress provided the EPA administrator with the authority, for FY 2006–2015 and after consultation with the Office of Personnel Management, to employ up to 50 persons at any one time in ORD. The committee notes, however, that the number of Title 42 appointments is not so limited in several other federal agencies that fill scientific positions by using Title 42 authority. According to the US Government Accountability Office, in 2010, the Centers for Disease Control and Prevention had 929 Title 42 employees, the US Food and Drug Administration had 862, and the National Institutes of Health had 4,879.[8] The committee agrees with the 2010 NRC report on Title 42. **EPA should be granted permanent Title 42 authority and the expanded authority to define the number of Title 42 positions on the basis of its program needs and available budget. In addition, EPA should use an independent body to review the Title 42 program every 5 years to ensure that it is being used for its intended purposes.** ***(Recommendation 3-7)***

SYNERGIES WITH OTHER ORGANIZATIONS

An effective EPA laboratory enterprise should be fully cognizant of the array of research conducted outside EPA laboratories, should have mechanisms and programs to capitalize on that scientific work, and should have plans and staffs in its own laboratories not only to accomplish work necessary for its mission but to complement efforts of other agencies and to provide a means of collecting, sorting, and analyzing the results of those efforts to serve EPA's mission. Data needed to address environmental issues are being generated globally at an enormous rate. To supplement the work of its laboratory enterprise and to use its laboratory facilities and scientific staff efficiently, it is critical for EPA to have a strong capability for accumulating, managing, and mining extremely large and relevant datasets from diverse sources outside EPA. These sources include other federal agencies (such as the Department of the Interior and Department of Agriculture), state agencies (such as departments of health and environment), and private industry (such as motor vehicle manufacturing) in the United States and abroad. **EPA should develop more explicit plans for partnering with other agencies** (federal and state), academia, industry, **and other organizations to clarify how it uses other federal and nonfederal knowledge resources, how it maintains research capabilities that are uniquely and critically needed in the agency, and how it avoids unnecessary duplication of the efforts or capabilities of the other agencies.** ***(Recommendation 4-12)***

State-of-the-art facilities and equipment are essential for an outstanding laboratory enterprise to be able to meet current and future mission needs. ORD, program office, and regional office laboratories have various processes for managing and acquiring laboratory equipment, but the processes and inventory tools throughout the agency are not connected. **EPA should link inventories of equipment over $500,000 in all laboratories, without regard to mission, to an agencywide accessible process. Before investing in large capital equipment, laboratory equipment in other parts of EPA, other agencies, and universities that could be available for shared use should be explored.** ***(Recommendation 3-9)***

ADDRESSING FUTURE CHALLENGES

Examples of important emerging environmental challenges include human and environmental exposure to toxic chemicals, loss of native biodiversity, and new stressors from climate change that affect human health, the built infrastructure, social institutions, and natural ecosystems. A variety of informal and formal approaches that EPA can use for identifying emerging issues and possible solutions are available,

[7]NRC, 2010. *The Use of Title 42 Authority at the U.S. Environmental Protection Agency*.
[8]GAO. 2012. *Human Capital: HHS and EPA Can Improve Practices Under Special Hiring Authorities*. GAO-12-692.

including ongoing interactions with state and local governments and formal analyses of future societal scenarios and their ramifications. Advisory groups, such as EPA's Science Advisory Board (SAB) and advisory bodies established to provide independent expert advice to specific types of EPA laboratories, can also contribute to the process of identifying and evaluating emerging issues.

When faced with a serious emerging issue or important opportunity to take advantage of new knowledge or technologies, the agency could marshal the various institutional research tools that it has already developed into a small E-ARPA (an Environmental Advanced Research Projects Alliance).[9] The agency could involve universities and the private sector through its ability to develop cooperative agreements, issue contracts and grants through its STAR grants program, and coordinate the different departments of the government and the different elements of its own scientific expertise. **EPA should consider creating an Environmental Advanced Research Projects Alliance (E-ARPA) and also consider how and under what circumstances E-ARPA efforts could be managed to address the agency's scientific and technical needs.** ***(Recommendation 5-2)*** Although it did not attempt to estimate the funding requirements for this alliance, the committee does not anticipate that E-ARPA would involve a programmatic effort of comparable magnitude to DOD's and DOE's programs.

EPA's workforce, makeup of expertise among workforce personnel, and management are important elements of its efforts to identify and address emerging issues. A focused commitment by career managers and political appointees is essential for sound decision-making and for maintaining a workforce that is capable of identifying and dealing with emerging issues.

CONCLUDING REMARKS

Given the principles and recommendations provided in this report, we believe that EPA has the tools to design and implement a plan for enhancing its network of laboratories. The actions that the agency takes to improve the effectiveness and efficiency of its laboratory enterprise should be organized around the concept of a system that maintains the strength of the individual laboratory types while providing systematic collaboration and communication throughout the agency. The committee recognizes that some of the recommendations may be difficult to undertake, and that sufficient resources may not be available to undertake them all in the near term. Therefore EPA will need to set priorities and develop a strategy for addressing them as part of its integrated evaluation of agency laboratories.

[9]The Department of Defense's Defense Advanced Research Projects Agency (DARPA) and the Department of Energy's (DOE's) Advanced Research Projects Agency–Energy (ARPA-E) program are examples of robust programs that are used to anticipate developments and possible responses. The name of the suggested EPA program is patterned after, but different from, DOE's ARPA-E.

1

Introduction

COMMITTEE'S STATEMENT OF TASK

The US Environmental Protection Agency (EPA) is undertaking an integrated evaluation of its laboratories for the purposes of strengthening the management, effectiveness, and efficiency of its laboratory network and enhancing its capabilities for research and other laboratory-based scientific and technical activities; addressing US Government Accountability Office (GAO) recommendations that EPA improve cohesion in managing and operating agency laboratories (GAO 2011); and helping the EPA laboratory enterprise[1] respond to change and be equipped to handle emerging scientific challenges (Perciasepe 2013). EPA's initiative will conclude with the administrator's guidance on changes to strengthen the laboratory enterprise and its portfolio of physical facilities.

As part of that effort, EPA sought independent expert advice from the National Research Council, which established the Committee on Strengthening the US Environmental Protection Agency Laboratory Enterprise: Phase 1—Priority Needs, Guiding Principles, and Overall Goals. The statement of task (Box 1-1), developed in consultation with EPA, served as a guide for the committee's work. The committee was asked to assess EPA's highest-priority needs for mission-relevant laboratory science and technical support, develop principles for the efficient and effective management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals, and develop guidance for enhancing efficiency and effectiveness now and during the next 10 years.

The committee was asked not to assess the organization, the facility-level and portfolio-level master plans, or the consolidation initiatives of EPA's laboratory enterprise; that analysis is being undertaken in a separate effort. SmithGroupJJR (an architectural and engineering firm) is assisting EPA with the analysis of data collected by EPA on the current portfolio of laboratory facilities. Topics being considered during the analysis include how efficiently facility space is used and the current operating costs of the facilities.[2] An EPA work group will consider the committee's input and the results of the separate portfolio-level analysis in developing options for improving the efficiency and effectiveness of EPA's laboratories, including options for colocation and consolidation. The EPA work group also will recommend an implementation plan for consideration by the EPA administrator and deputy administrator (Paulson 2014). Therefore, the committee was asked not to recommend a reorganization of the laboratory enterprise.

COMMITTEE'S APPROACH TO ITS TASK

At the committee's first meeting, EPA officials indicated that the committee was not expected to develop a new list of the agency's highest-priority needs for mission-relevant laboratory science and

[1]"The EPA laboratory enterprise is the aggregate capability and capacity required by its laboratories and laboratory-based centers to meet the agency's high-priority mission needs of its programs and strategic goals" (Paulson 2013a).

[2]The results of the portfolio-level analysis were not available to the committee as it was carrying out its study.

technical support but that instead the committee was to assess the highest-priority needs identified previously by EPA on the basis of mission relevance, legislative mandates, and guidance from EPA's strategic plan, which is revised every 4 years. Therefore the committee considered EPA's current highest-priority needs to be those associated with major pollution laws administered by the agency and the goals and objectives identified in EPA's strategic plan. They are described later in this chapter. EPA officials also indicated that the National Research Council report *Science for Environmental Protection: The Road Ahead* (NRC 2012a) provides a good basis for identifying priorities for the agency for the next 10 years (The priorities identified in that report are provided in this chapter).

Consistent with its statement of task, the committee identified various opportunities where EPA laboratories could become more effective and efficient through a rethinking of its overall system of laboratories. One of the committee's prime activities was to understand the makeup and function of EPA's "laboratory enterprise", which is the subject of the study charge. Although GAO (2011) used the term extensively, there is no readily available guide to how the various types of facilities within the enterprise fit together. In preparing its report, the committee attempted to define the characteristics and dynamics of the enterprise and provide principles and recommendations for its management. It did not attempt to develop principles and recommendations for specific laboratories. Likewise, the committee considered the breadth and complexity of EPA's highest-priority science needs collectively in developing principles and recommendations for the agency's laboratory enterprise. The committee did not attempt to develop guidance for meeting specific priority needs individually.

BOX 1-1 Statement of Task

An NRC committee will assess EPA's highest priority needs for mission-relevant laboratory science and technical support, now and during the next ten years. Recognizing the need to operate within budget constraints and growing demands, and recognizing the potential contributions of external sources of scientific information from other government agencies, industry, and academia in the U.S. and other nations, the committee will develop principles for the efficient and effective management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals. Drawing upon these principles, the committee will develop guidance for enhancing efficiency and effectiveness, now and during the next ten years, which:

– Improves EPA's ability to plan, prioritize, coordinate, and deliver scientific research, technical support, and analytical services from EPA's laboratory enterprise for achieving the highest-priority scientific needs and strategic goals, and for achieving the strategic objectives in the GPRA Modernization Act of 2010 for laboratory and research organizations;
– Uses an analytical framework(s) to ensure that laboratory facilities, functions, scientific solutions, and capabilities are aligned with the highest-priority scientific needs for the agency's strategic goals; and
– Sustains the leadership capability of the laboratory enterprise for environmental science and research.

The committee's work is part of a multi-phase effort by EPA and collaborating organizations to make the agency's laboratory enterprise more effective and efficient while reducing costs. The committee will not assess the organization, or the facility-level and portfolio-level master-plans, or the consolidation initiatives for EPA's laboratory enterprise, because that analysis will be undertaken through a separate effort. EPA will consider the findings and recommendations provided by the committee, as well as the input from other efforts, in developing an implementation plan for the laboratory enterprise. At EPA's discretion, another ad hoc NRC committee may be asked subsequently and funded separately to assess the draft plan.

The committee has developed principles and recommendations relevant to aligning laboratory functions with the highest-priority needs, workforce, laboratory equipment, management and leadership, and planning. It considered and built on the relevant findings and recommendations of previous reports from the National Research Council, GAO, and other organizations (see Appendix D). The present report does not address the physical space and configuration options of laboratory facilities, which are being addressed under a contract with SmithGroupJJR. Although there was no opportunity to receive any results of or reports on the work of SmithGroupJJR, it is the committee's understanding that the firm is not addressing laboratory equipment issues.

Although it is possible that the agency's laboratory system functions optimally by having each type of laboratory work well on its own, it is the committee's view that greater efficiency and effectiveness could be gained through systematic collaboration and communication. Based on information provided by EPA, the committee considered the extent to which examples of greater coordination between laboratories appeared to be systematic or ad hoc, and what additional benefits could be achieved by extending the coordination and communication throughout the agency's laboratory enterprise.

Regarding EPA's laboratory workforce, the committee recognized that budgetary constraints over the past few years have made it difficult for the agency to hire people with the necessary skills for addressing current and emerging complex problems. The committee examined how tools and programs EPA currently uses, or had used in the recent past, for workforce development could be enhanced. For laboratory equipment, the committee considered where connecting EPA's processes for managing and acquiring laboratory equipment across the enterprise might present potential opportunities for enhanced efficiency, such as increased sharing of equipment.

Although following the committee's recommendations may result in efficiency gains that, in turn, may result in lower resource requirements for EPA, the committee realizes that implementing its recommendations is not without cost. However, the committee was not asked to and did not attempt to estimate the implementation costs associated with its recommendations.

THE ENVIRONMENTAL PROTECTION AGENCY'S MISSION

EPA was created in 1970 in response to public alarm and mounting political pressure over degradation of the environment from air, water, and pesticide pollution. Its creation was accomplished by Executive Order 1110.2, which transferred duties related to 15 environmental programs from five departments and one commission to the new agency, whose stated mission was "to protect human health and the environment". Specifically, EPA's purpose is to ensure that

- all Americans are protected from significant risks to human health and the environment where they live, learn and work;
- national efforts to reduce environmental risk are based on the best available scientific information;
- federal laws protecting human health and the environment are enforced fairly and effectively;
- environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade, and these factors are similarly considered in establishing environmental policy;
- all parts of society—communities, individuals, businesses, and state, local and tribal governments—have access to accurate information sufficient to effectively participate in managing human health and environmental risks;
- environmental protection contributes to making our communities and ecosystems diverse, sustainable and economically productive; and
- the United States plays a leadership role in working with other nations to protect the global environment.(EPA 2014a).

When it was established, EPA was given statutory authority to provide the regulatory framework for and enforce environmental-pollution laws and to conduct research to support policy development that underpins such efforts. The agency now has responsibility for implementing some 33 laws, congressional mandates, executive orders, and presidential directives. Of those, 10 major federal pollution-control laws drive the bulk of the agency's activity and budget (Bearden et al. 2007, Table 1-1). The 10 laws are complex to implement, and they create a continuing demand for specific kinds of scientific research and other knowledge that motivate much of the agency's scientific endeavors (Bearden et al. 2007).

Science underpins the achievement of EPA's goals by providing information to support a variety of activities from enforcement of current laws and regulations to development of new regulations and identification of threats to public health and the environment. At the time of its creation, EPA was mandated to establish six program offices (some of which were focused on specific environmental media), an assistant administrator to direct the Office of Research and Monitoring (now the Office of Research and Development, ORD), and 10 regional offices whose role was to directly support and interact with the 50 states and territorial and tribal jurisdictions that were responsible for implementing environmental-pollution monitoring, control, enforcement, and cleanup. It "inherited 42 laboratories from programs in various federal departments, including the Department of the Interior; the former Department of Health, Education, and Welfare; and the US Department of Agriculture" (GAO 2011). Although some laboratories have been closed or consolidated since the establishment of EPA, most of the current EPA laboratories remain in the original locations for political, logistic, and other pragmatic reasons. EPA has three general types of laboratories, as discussed below.

THE ENVIRONMENTAL PROTECTION AGENCY LABORATORY ENTERPRISE

EPA's laboratory enterprise consists of a distributed network of three general types of laboratories, as discussed below.

National Program Office Laboratories

Six laboratories and two centers support five national regulatory program offices—the Office of Air and Radiation (OAR), the Office of Chemical Safety and Pollution Prevention, the Office of Enforcement and Compliance Assurance (OECA), the Office of Water (OW), and the Office of Solid Waste and Emergency Response (OSWER).

National program laboratories have primary responsibility for implementing legislative mandates to develop and provide specific information that supports decisions regarding regulations, compliance, and enforcement at a national level. For example, EPA has been tasked with enforcement of such regulations as vehicle tailpipe-emission regulations and with providing information to the public, such as vehicle mileage performance; the OAR National Vehicle and Fuel Emissions Laboratory performs the motor-vehicle standards and performance testing to provide the needed information. Another OAR laboratory is devoted to assessing radiation risks. Two laboratories in the Office of Chemical Safety and Pollution Prevention support the agency's pesticide registration and enforcement program. National enforcement efforts are supported by the OECA National Enforcement Investigations Center, which investigates violations of environmental laws and provides technical and forensic services to support for civil and criminal investigations. The center also provides counsel on legal and policy matters.

To augment its intramural analytic capabilities, OSWER contracts with private-sector organizations through the Contract Laboratory Program to carry out laboratory-related activities, primarily to support waste-site remediation projects.

TABLE 1-1 Summary of Major Pollution Laws Administered by EPA

Law	Purpose	Science Requirements
Clean Air Act	Requires EPA to set mobile-source limits, ambient-air quality standards, hazardous air-pollutant emission standards, standards for new and existing pollution sources, and deterioration requirements and to focus on areas that do not attain standards	Set national standards for air quality, monitor and model air quality for implementation plans, identify best available control for new point sources, set mobile source and emission standards, implement acid-rain control program
Clean Water Act	Establishes a sewage-treatment construction grants program and a regulatory and enforcement program for discharges of wastes into US waters	Establish national standards or effluent limitations
Comprehensive Environmental Response, Compensation, and Liability Act	Superfund—provides authority for the federal government to respond to releases of hazardous substances and establishes a fee-maintained fund to clean up abandoned hazardous-waste sites	Develop and apply Hazard Ranking System to identify the most hazardous sites in the United States and to prioritize and develop response actions
Emergency Planning and Community Right-to-Know Act	Requires industrial reporting of toxic releases and encourages planning to respond to chemical emergencies	Establish categories of health and physical hazards for reporting purposes; establish data and information summaries via the Toxics Release Inventory
Federal Insecticide, Fungicide, and Rodenticide Act	Governs pesticide products and their uses	Assess human and wildlife risk posed by pesticides and ensure that such assessments maintain scientific currency
Ocean Dumping Act	Regulates intentional disposal of materials into ocean waters and authorizes related research	Conduct general research on ocean resources and long-term research on ecosystem effects of ocean dumping, pollution, overfishing, and other human activities
Pollution Prevention Act	Seeks to prevent pollution through reduction in generation of pollutants at their point of origin	Identify source-reduction approaches; develop, test, and disseminate model source-reduction auditing procedures to highlight opportunities; promote research on and development of source-reduction techniques and processes.
Safe Drinking Water Act	Establishes primary drinking-water standards, regulates underground injection disposal practices, and establishes a groundwater and surface-water quality control program	Identify causes of, diagnosis methods for, treatment for, control of, and prevention of diseases and other impairments resulting from contaminants in drinking water; set national standards for drinking-water contaminants; identify and set priorities for contaminants that warrant regulation on the basis of human health risk analysis; identify cost-effective treatment technologies; assess water-supply vulnerability to terrorist attacks; and provide guidance on emergency-response approaches
Solid Waste Disposal Act/Resource Conservation and Recovery Act	Regulates solid and hazardous waste	Establish minimal national standards for hazardous-waste disposal and criteria for states to establish and enforce hazardous-waste programs, and advance research on hazardous-waste management
Toxic Substances Control Act	Regulates the testing of chemicals and their uses	Conduct and coordinate research, development, and monitoring related to toxic-substance screening, control, and risk management

Source: Bearden et al. 2007.

Regional Office Laboratories

Eleven laboratories are distributed among the 10 EPA regional offices—two in Region 3 and one in each of the others. The EPA regions are shown in Figure 1-1. The primary responsibilities of these laboratories include providing scientific data to support decisions by the regions' environmental programs and to inform immediate and near-term decisions on environmental conditions, compliance, and enforcement. To enforce federal laws and regulations, data on potential violations have to be gathered with legally defensible methods and in accordance with associated quality-assurance procedures. These enforcement actions are typically local and are supported by the network of regional office laboratories. Regional office laboratories also provide technical oversight of work carried out by state agency laboratories, such as assessment of the quality of data that result from drinking-water testing by state laboratories.

Office of Research and Development Laboratories

To improve the basis of the regulations needed to protect public health and environmental quality, it is necessary to improve the scientific understanding of environmental functioning and its interactions with people. ORD laboratories are responsible for performing research and assessing findings developed with support of other agencies and research institutions to provide the basis of standards and regulations and to anticipate emerging threats to health and the environment. ORD consists of seven divisions of the National Health and Environmental Effects Research Laboratory, five divisions of the National Risk Management Research Laboratory, six divisions of the National Exposure Research Laboratory, and six research centers in four national center facilities.

Since 2001, homeland security has also been an important consideration in environmental protection. ORD's National Homeland Security Research Center, created by a presidential directive after the bioterrorism incidents after 9/11, established the Emergency Response Laboratory Network (ERLN) to respond to, monitor, and remediate incidents of chemical, biologic, and radiologic (CBR) hazard. ERLN is structured as a distributed and virtual laboratory capable of responding to geographically dispersed CBR threat incidents, accidents, and natural disasters in diverse urban and environmental settings. All ORD program and regional laboratories participate in ERLN. The network also encompasses state-based facilities, commercial laboratories, and laboratories and networks of other federal agencies—such as those of the Centers for Disease Control and Prevention, DOE, and the US Department of Agriculture—to achieve critical technical capability, manpower, and concentrated resources to respond to an emergency.

Definition of *Laboratory*

Given the complex and broad duties of the agency in responding to all its statutory requirements and mandates to meet its mission, it is remarkable that EPA can accomplish its mission within current budget constraints. One indication of its size relative to its mission is that the full-time equivalent allocation to ORD and its budget (not including laboratories in regions or program offices) are roughly equivalent to those of a single, smaller Department of Energy (DOE) national laboratory.

Communications about the size of the laboratory enterprise are often complicated by the fact that different groups in and outside EPA apply different definitions to *laboratory*. In its communications, EPA does not consistently categorize a laboratory entity among its national program laboratories, its regional office laboratories, and the laboratories, divisions, and centers in the ORD laboratories. Therefore, the discrete components of the laboratory enterprise are not well defined. For the present report, we consider the laboratory enterprise to include the laboratories, divisions, and centers listed in Appendix E.

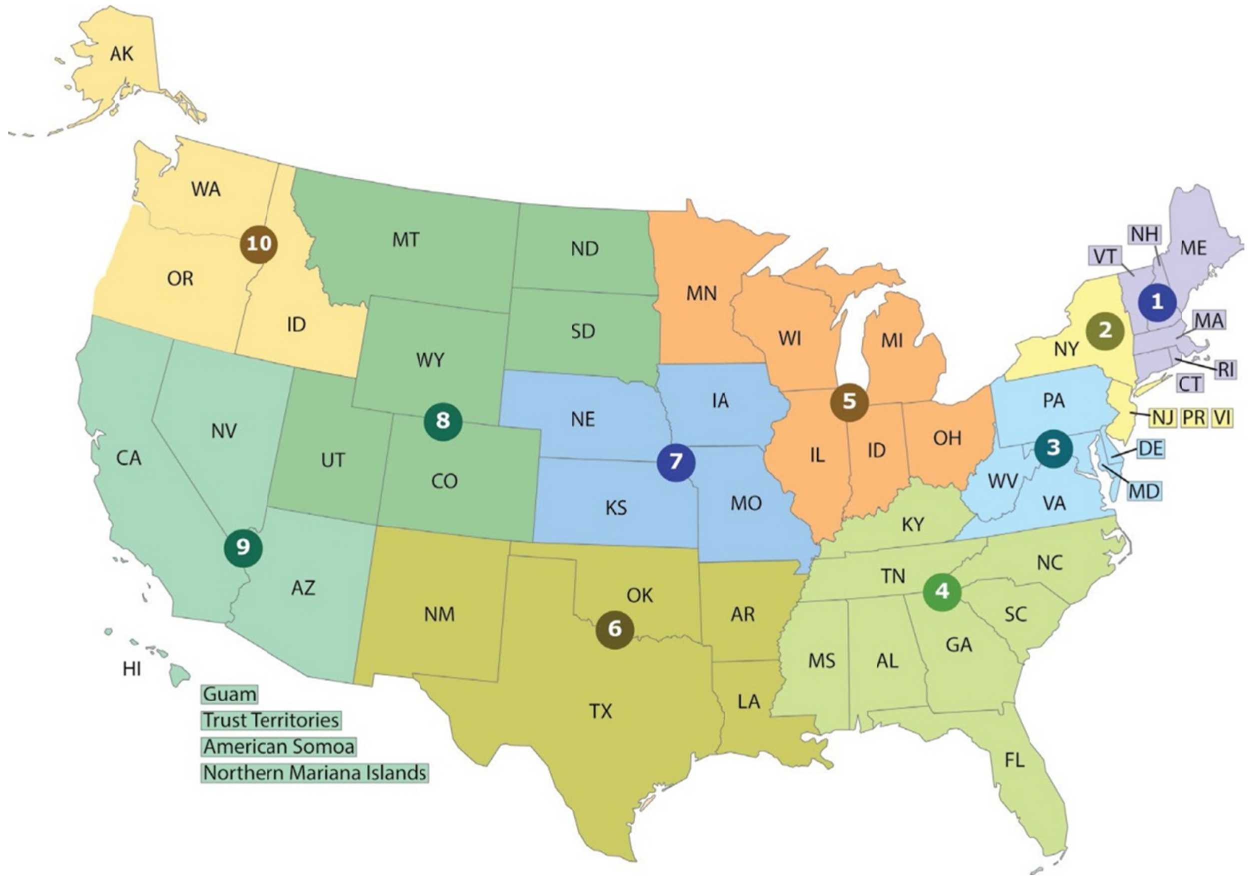

FIGURE 1-1 EPA regions in the United States. PR and VI in Region 2 refer to Puerto Rico and the Virgin Islands, respectively.

EPA uses the term *laboratory* in two contexts. One is that of a discrete physical space of a traditional utilitarian research, development, or testing activity that may be devoted to a single technical product or medium-specific activity. The other is that of a large multipurpose structure or collection of structures, perhaps not even in the same location, that focus on a large programmatic theme or a multifaceted research or technology effort. Confounding the designation is that similar entities may be described as centers instead of laboratories, and there appears to be no formal—or at least stated—hierarchic definition of the different entities. That may be due in part to a historical medium-specific function of laboratories inherited at EPA's formation. It may also be due to an attempt to ascribe functional activities to some facilities that link them to programmatic goals and thrusts of the agency. All this lends a degree of confusion to outside evaluation of the utility, efficiency, and productivity of a unit referred to as a laboratory.

As described above, a degree of semantic confusion leads to different estimates of the number of laboratories that the agency operates. Further confounding the situation is the jumble of acronyms used to refer to the laboratories and their program offices. For instance, the National Air and Radiation Environmental Laboratory in Montgomery, AL (see Appendix E) is also referred to as the National Analytical Radiation Environmental Laboratory, using the same abbreviation (NAREL). To say the least, the morphing of names and abbreviations for laboratories, program offices, and research programs makes for a daunting challenge in following lines of responsibility and goals.

Overall, the committee found that the term *laboratory* is applied in many circumstances with regard to EPA's science and technical assistance functions. Moreover, EPA does not clearly define how its laboratories interact. Clear definitions of *laboratory* and *laboratory enterprise* are essential. Because of the complexity of EPA's laboratory enterprise, a single principle might not apply to all aspects of it.

EPA's laboratory enterprise is part of the larger scientific endeavor within the agency (see Figure 1-2). The larger endeavor is summarized below to provide context for the discussion of the laboratory enterprise in this report.

SCIENCE IN THE ENVIRONMENTAL PROTECTION AGENCY

EPA science entails a wide array of activities, from scientific assessments and reviews to observational and experimental research, modeling, cross-disciplinary synthesis, benefit–cost analysis, and risk analysis. As summarized by the National Research Council Committee on Science for EPA's Future (NRC 2012a, pp. 107–108), those activities should meet a number of objectives, notably to

- Support the needs of the agency's regulatory mandates and timetables, informing decisions about regulatory health standards, policies, risk management, emergency response, compliance, and enforcement.
- Identify, build, and maintain the intellectual foundations that will allow the agency to meet current and emerging environmental challenges over the next several decades.
- Set priorities for information and research needs.
- Sustain and continually rejuvenate inhouse research staff and associated laboratories and field capabilities to meet the mission needs of the agency in active collaboration with its partners.
- Appropriately balance inhouse and extramural research investment.

More than 6,000 full-time EPA employees involved in research and other science-related activities are distributed throughout the agency (EPASAB 2012). About 1,450 of them are in ORD, and about 4,700 in program and regional offices. On the basis of information provided by EPA for 2013 (see Appendix E), the laboratory workforce—which includes scientific researchers, technicians, engineers, support staff , and administrative staff in laboratories as opposed to headquarters or program and regional offices—totals roughly 3,630 persons, or about 60% of the agency's total science workforce. About two-thirds of those are federal personnel (Appendix E).

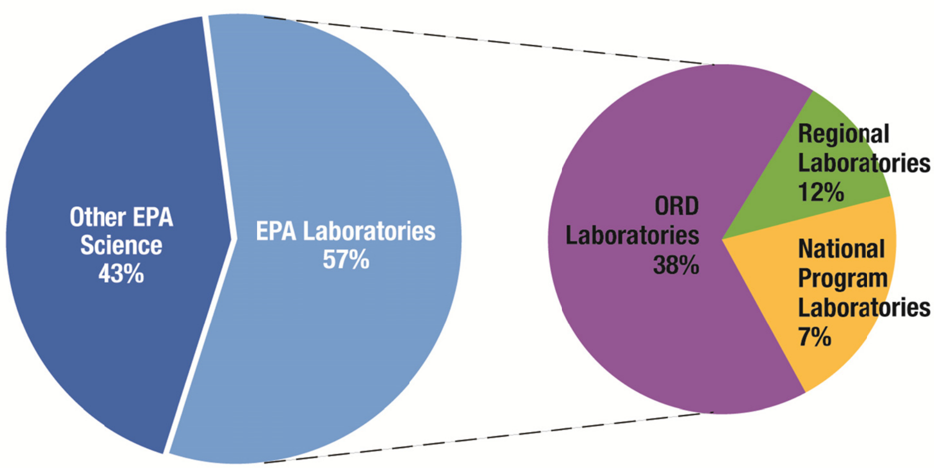

FIGURE 1-2 The EPA laboratory workforce as a fraction of its total workforce and the national program laboratories, regional office laboratories, and ORD laboratories as fractions of the laboratory workforce (see Appendix E).

Since 1970, EPA has played an important and often a leadership role in advancing many fields of environmental science and engineering, notably ecologic and health sciences, environmental chemistry, environmental monitoring, pollution fate and transport, environmental remediation, ecotoxicology, vehicle efficiency, and emission control. That role has been especially important in generating scientific information that has provided a basis for regulatory decisions (summarized in NRC 2012a). For example, the agency has a long history of leadership in air-pollutant modeling (NRC 2012a); its Community Multiscale Air Quality model is widely used by researchers and agencies in the United States and abroad to model chemical transformations and transport processes of environmental pollutants, such as ground-level ozone, reactive nitrogen, and particulate matter. Since 2006, EPA has maintained a substantial computational-toxicology program whose objective is to develop approaches to the assessment and prediction of toxicity in vitro by using high-throughput testing. EPA scientists have produced new low-cost methods for monitoring landfill gas emissions with laser technology. The agency has advanced the use of molecular tools to track sources of microbial pathogens in surface waters and to set total maximum daily load standards. Similar advances have been made by EPA scientists and engineers in other fields of special relevance to the agency.

The agency's responsibility for regulation and enforcement creates a unique combination of drivers for its laboratory functions in providing fundamental knowledge and information to inform policy and rules; in establishing robust and defensible analytic methods to support monitoring, certification, and compliance; and in innovation to respond to environmental agents of new concern, forensic needs, terrorism, and natural disasters. Often, the agency's timetables and manpower staffing are driven by requirements imposed by Congress or the Executive Office of the President.[3] Science activities in support of the agency's regulatory mission are often conducted in the context of important policy-making and decision-making and under public scrutiny. Those factors contribute to a particularly challenging setting in which to build new, long-term science-based initiatives to meet emerging environmental challenges. In addition, tightening budget constraints can exacerbate an inherent tension between the agency's need to respond to immediate demands for expedited assessments and investigations for regulatory purposes and its longer-term program development to address current and future needs.

ENVIRONMENTAL PROTECTION AGENCY SCIENCE DIRECTIONS AND CHALLENGES

A recent National Research Council report provided a detailed analysis of persistent and emerging environmental challenges for EPA and of the need for new scientific theories and methods that can help to address the challenges (NRC 2012a). Key drivers of environmental change—such as population growth, land conversion, energy and water consumption, consumption of nonfuel materials, and transport of invasive exotic species—have increased considerably over the last 30 years and continue to increase. For example, annual vehicle miles traveled on US highways doubled from around 1.5 trillion miles in 1980 to 3 trillion miles in 2010 (DOT 2012). US nonfuel raw-material consumption (excluding imported goods) increased from 2.19 billion metric tons in 1980 to 3.89 billion metric tons in 2006 before decreasing to 2.57 billion metric tons in 2010 likely as a result of the global financial crisis (Matos 2012). Aggregate emissions of common air pollutants—such as carbon monoxide, lead, nitrogen oxides, volatile organic compounds, particulate matter, and sulfur dioxide—have declined by 63% since 1980 thanks to effective environmental policies, in particular the Clean Air Act (NRC 2012a), but other environmental problems and threats have proved less tractable, and some have increased dramatically (see Box 1-2).

[3]See, for example, the Regulatory Flexibility Act or Executive Order 12866 (1993) Regulatory Planning and Review.

BOX 1-2 Current and Emerging Environmental and Human Health Challenges for EPA

- Human and environmental exposure to increasing numbers, concentrations, and types of chemicals. Factors contributing to human and environmental exposures include energy choices, technologic change, and changing energy consumption.
- Threat of deteriorating air quality through changes in weather (Jacob and Winner 2009) and through the formation of more particles in the atmosphere from allergens, mold spores, pollen, and reactions of primary air pollutants (Confalonieri et al. 2007). Factors contributing to deteriorating air quality include population growth, energy choices, changing consumption, and climate change.
- Water quality and coastal-system degradation, including challenges to rebuild old infrastructure and address such issues as urban stormwater and bypass of raw sewage (NOAA 2012b). Factors contributing to water quality and coastal-system degradation include land use, urban sprawl, climate change, and energy systems.
- Non–point-source pollution and nutrient effects associated with agricultural runoff of nutrients and soils. Factors contributing to non–point-source pollution and nutrient effects include climate change, land use, and technologic change (NRC 2011).
- Expanding quantities of waste with a wider array of component materials (Schmitz and Graedel 2010). Factors contributing to expanding quantities of waste include population growth, energy usage, technologic change, and changing consumption.
- Expanding ecologic disruptions (USDA 2012). Factors contributing to ecologic disruptions include population growth, land use, climate change, and transport of organisms.

Source: NRC 2012a, p 32-33.

Advances in science and engineering and in associated tools and technologies are increasingly important in addressing environmental challenges. For example, improvements in analytic chemistry, advances in chemical fate and transport modeling, and new approaches and technologies for monitoring human exposure to chemicals in the environment are helping to meet the challenge of assessing the effect of human and environmental exposure to chemicals. At the same time, understanding and management of risks associated with those chemicals is changing, thanks to new tools in molecular biology (for example, genomics, proteomics, and metabolomics), such information technologies as bioinformatics, and systems-based approaches for predicting in vivo outcomes on the basis of multiple lines of evidence (NRC 2012a). In the air-pollution arena, coupling of air-quality models with regional atmospheric models is improving short-term forecasting. Models for understanding the interactions between climate change and regional air quality are being developed. Advances in aircraft and satellite remote sensing offer unprecedented opportunities for regional to global air-quality monitoring and prediction. Similar advances are occurring in the water-quality arena, notably in the ability to detect and attribute sources of pathogens and microbial populations in wastewater and surface waters (NRC 2012a). And ever more sophisticated tools in computer science and informatics are revolutionizing data collection (including public engagement), analysis, and reuse and thereby enabling new kinds of data-intensive science and synthesis research (Michener and Jones 2012).

EPA's ability to address emerging environmental challenges with cutting-edge tools and technologies is strongly conditioned by and intertwined with its role as a regulatory agency. For example, improved detection capabilities would enhance the agency's capabilities of evaluating the effectiveness of chemical-pollutant regulations (NRC 2004).

STRATEGIC SCIENCE GOALS AND RESOURCE ALLOCATION

To achieve its mission, EPA develops a 4-year strategic plan that defines its goals. In the current strategic plan, EPA outlines the following goals and objectives (EPA, 2014b, Table 1-2):

TABLE 1-2 Goals and Objectives in EPA's Current Strategic Plan

Goal	Objectives
1. Addressing Climate Change and Improving Air Quality	– Minimize the threats posed by climate change by reducing greenhouse gas emissions and taking actions that help to protect human health and help communities and ecosystems become more sustainable and resilient to the effects of climate change. – Achieve and maintain health- and welfare-based air pollution standards and reduce risk from toxic air pollutants and indoor air contaminants. – Restore and protect the earth's stratospheric ozone layer and protect the public from the harmful effects of ultraviolet (UV) radiation. – Minimize releases of radioactive material and be prepared to minimize exposure through response and recovery actions should unavoidable releases occur. (p. 8)
2. Protecting America's Waters	– Achieve and maintain standards and guidelines protective of human health in drinking water supplies, fish, shellfish, and recreational waters, and protect and sustainably manage drinking water resources. – Protect and Restore Watersheds and Aquatic Ecosystems. Protect, restore, and sustain the quality of rivers, lakes, streams, and wetlands on a watershed basis, and sustainably manage and protect coastal and ocean resources and ecosystems. (p.18)
3. Cleaning Up Communities and Advancing Sustainable Development	– Support sustainable, resilient, and livable communities by working with local, state, tribal, and federal partners to promote smart growth, and reuse of contaminated and formerly contaminated sites, and the equitable distribution of environmental benefits. – Conserve resources and prevent land contamination by reducing waste generation and toxicity, promoting proper management of waste and petroleum products, and increasing sustainable materials management. – Prepare for and respond to accidental or intentional releases of contaminants and clean up and restore polluted sites for reuse. – Directly implement federal environmental programs in Indian country and support federal program delegation to tribes. Provide tribes with technical assistance and support capacity development for the establishment and implementation of sustainable environmental programs in Indian country. (p. 28)
4. Ensuring the Safety of Chemicals and Preventing Pollution	– Reduce the risk and increase the safety of chemicals that enter our products, our environment, and our bodies. – Conserve and protect natural resources by promoting pollution prevention and the adoption of other sustainability practices by companies, communities, governmental organizations, and individuals. (p. 39)
5. Protecting Human Health and the Environment by Enforcing Laws and Assuring Compliance	– Pursue vigorous civil and criminal enforcement that targets the most serious water, air, and chemical hazards in communities to achieve compliance. – Assure strong, consistent, and effective enforcement of federal environmental laws nationwide. Use Next Generation Compliance strategies and tools to improve compliance and reduce pollution. (p. 47)

Source: EPA, 2014b.

Science underpins the achievement of those goals by providing the information needed to support a variety of activities, from the enforcement of current laws and regulations to the development of new regulations and identification of threats to public health and the environment. The alignment of strategic goals and laboratory activities is summarized in Table 1-3. In preparing a budget request, EPA does not provide requests for individual laboratories, types of laboratories, or the entire enterprise. Therefore, it is not apparent from an outsider's view of the budget how resources given to the agency for its scientific functions correspond with laboratory activities. However, it is apparent that EPA faces a substantial challenge in using available resources to meet all its priority needs for laboratory science and technical support, which may change with factors, such as congressional deadlines, new mandates, changing administrations, and the unknown, such as massive oil spills.

TABLE 1-3 Science Contributions from EPA Laboratories

LAB	GOAL 1	GOAL 2	GOAL 3	GOAL 4	GOAL 5
Regional Labs	Yes	Yes	Yes	Yes	Yes
Program Labs					
NEIC-CO					Yes
OW-OH		Yes			
OAR-MI	Yes				
OAR-AL	Yes	Yes	Yes	Yes	
OCSPP-MD		Yes		Yes	
OCSPP-MS			Yes	Yes	
ORD Labs	Yes	Yes	Yes	Yes	Yes

Source: Paulson 2013b.

Through management, strategic priority-setting, leveraging of resources with stakeholders and other agencies, and the work of committed professionals, the agency has built a laboratory-science capability in support of its mission. Whether it can maintain that status, respond to future environmental threats, and continue to protect the public health remains an open question in light of the current budget climate. For example, the agency operates in a climate of shrinking resources, which results in great reduction in the ability to make up for the loss of seasoned personnel.

ORGANIZATION OF THE REPORT

The committee's work required considerations at the intersection of diverse fields, including environmental program design and management; toxicology; environmental medicine; environmental health; engineering; environmental law; environmental policy, regulation, and risk management; and ecologic and health risk assessment. The following chapters provide some brief, fundamental background on those topics as a basis for discussions and recommendations. The committee's charge was to develop principles for the efficient and effective management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals in the present and during the next 10 years. Chapter 2 provides an analytic framework in which EPA can efficiently and effectively deliver the scientific outputs that will contribute to health and environmental protection outcomes. Chapter 3 identifies summary principles of a high-quality laboratory enterprise and focuses specifically on the workforce and equipment. Although physical facilities constitute a critical element of a laboratory system, that aspect is being addressed in a separate effort, as discussed above. In Chapter 4, the committee addresses the management processes that would help to tie the enterprise together, focusing on planning, implementation, assessment, and communication within EPA. Chapter 5 discusses approaches for identifying emerging challenges, and Chapter 6 presents all the principles identified in this report and links them to the committee's recommendations.

2

Analytic Framework

PURPOSE OF THE ANALYTIC FRAMEWORK

As discussed in Chapter 1, science underpins the achievement of Environmental Protection Agency (EPA) strategic goals by providing information to support activities as varied as enforcement of laws and regulations to the development of new regulations and identification of future threats to public health and the environment. To support its science-based activities, EPA operates laboratories for various purposes.

Given the multiple and complex needs for scientific data and insights to fulfill its mission, an analytic framework is needed to determine how EPA can effectively and efficiently deliver the scientific information that will support decision making for health and environmental protection. This chapter will describe that framework.

TOUCHSTONES OF EFFICIENCY AND EFFECTIVENESS

The analytic framework includes general criteria for evaluating EPA's laboratory enterprise and shaping EPA's investments, processes, and planning to ensure the enterprise is aligned with the agency's highest-priority needs. More-detailed criteria are provided in Chapter 4. In its 2008 report *Evaluating Research Efficiency in the U.S. Environmental Protection Agency*, the National Research Council characterized two criteria—efficiency and effectiveness—as central in evaluating the performance and results of EPA's research and development program. Those criteria are also of central importance in analyzing EPA's laboratory enterprise. In defining *efficiency* and *effectiveness*, we draw on the 2008 report but expand the definitions to apply beyond EPA's Office of Research and Development (ORD) to the full array of laboratory science programs supporting EPA's mission.

Efficiency is the laboratory enterprise's ability to produce relevant, high-quality, timely, and cost-effective results to fulfill the agency's mission. It includes both investment efficiency (Is the laboratory enterprise doing the right work and doing it well?) and process efficiency (Is it doing this work in a timely and cost-effective way?) (NRC 2008). Investment efficiency requires planning and budgeting to ensure that laboratory resources (both physical and human) are deployed to address the priorities and projected needs of EPA's program offices and regions at a high level of quality. EPA's laboratory assets are distributed among many parts of the agency, investment efficiency requires a coordinated agencywide process that can direct resources and activities to where they are needed most. It also requires adaptive adjustments to reflect new scientific information, sources, and methods and changes in agency priorities. The 2008 report concluded that investment efficiency cannot be assessed quantitatively and should be the subject of expert review. Process efficiency focuses on the management of the laboratory enterprise, particularly its ability to produce timely results with little waste. Unlike investment efficiency, it can be measured according to quantitative benchmarks (or standards) of dollars spent or hours worked.

In describing efficiency, the 2008 report distinguished among inputs, outputs, and outcomes. Inputs are resources—funds, facilities, and people—that support EPA's science-related activities. Outputs are activities or products of science programs. They include not only the products of EPA's research laboratories—such as published papers, new scientific methods, and enhancement of research capacity—but monitoring of results, compliance tests, enforcement investigations, and other outputs of regional and program laboratories (NRC 2008). Outcomes are the benefits resulting from the science programs. They encompass both intermediate (programmatic) and ultimate (environmental or health) outcomes. The 2008 report concluded that ultimate outcomes—environmental or health end points—do not constitute a useful criterion for evaluating EPA research, because ultimate outcomes usually cannot be reasonably estimated in advance, may occur long after research is completed, and usually depend on actions taken by others. Programmatic benefits, however, constitute a useful and important criterion. In our analysis, programmatic benefits include not only advances in scientific knowledge or comprehensive assessments necessary for agency policy-making but advances in monitoring and testing capability and other outcomes that are necessary for effective implementation and enforcement.

Effectiveness is the ability to achieve useful results (NRC 2008). It focuses on the utility of laboratory enterprise outputs and outcomes to the agency's science consumers. It captures the importance of the link between the work of EPA's laboratories and the agency's mission. The work needs to be not only relevant, of high quality, and cost-effective but of maximum usefulness in meeting the priorities and expected needs of the program offices and regions.

Those general criteria can be elaborated in their application to the diverse functions and processes of EPA's laboratory enterprise. As discussed in Chapter 1, EPA laboratories serve various functions, from laboratory science and assessments to compliance certifications to field investigations and enforcement. Efficiency and effectiveness are relevant to each function but are measured differently for each. For example, measures of the usefulness of a laboratory study in supporting a major rule-making will differ from measures of its usefulness in sampling groundwater to characterize risks at a contaminated site.

Each laboratory function goes through multiple stages—from planning and budgeting to implementation to production of outputs and outcomes. Efficiency and effectiveness are relevant at each stage but vary in content among them. For example, efficiency concerns in the planning phase (such as alignment with strategic goals and program priorities) differ from those in implementation (such as cost-effective deployment of assigned resources).

Assessing effectiveness and efficiency requires a number of more specific criteria, and these will help to serve as the basis of the analytic framework in the next sections, and further elaborated in Chapter 4. To be effective and efficient, the various laboratories have to provide a "critical mass" of capabilities that include physical facilities and intellectual capital. The physical facilities need to support modern scientific efforts, for example, ultratrace analysis free of background contaminants. Most ORD laboratory facilities have been in operation for many years. They may have a legacy of residual contamination from work conducted when ambient concentrations were high, and they may not be able to support new types of equipment or systems that would permit the scientific staff to pursue studies of importance to the agency. The availability of space that can be readily adapted to a changing set of science priorities would offer the opportunity for research staff to continue to operate at the frontiers of science. However, it is not clear that EPA research must be conducted only in facilities dedicated to EPA activities. Given the panoply of federal and university laboratory facilities that have been developed to perform environmentally relevant research, it might make sense in some instances, for example, for some EPA employees to work in a Department of Energy (or other) laboratory where they could take advantage of unique capabilities. It would be useful to explore a wider array of approaches that take advantage of other research organizations that would permit EPA to perform the science that it requires to make informed decisions and implement science-based regulatory policies (see Chapter 4).

Like ORD laboratory facilities, program and regional office laboratory facilities need state-of-the-art equipment. Regional laboratories and program laboratories have as much need to keep equipment up to current standards as do ORD laboratories. In general, it appears that ORD laboratories have adequate access to equipment to maintain their capabilities. Assessments may be needed to determine equipment requirements for program and regional office laboratories to ensure that their equipment base is adequate to support their activities (see Chapter 3).

A critical issue facing EPA is the state of its scientific personnel. For a laboratory to be effective, it has to have employees with sufficient expertise for major projects that provide policy-relevant information or data to support regulatory action. The number of full-time-equivalent laboratory staff has decreased over the last 15–20 years, and many senior scientists are approaching retirement age. EPA staff has been augmented by on-site contractors and postdoctoral associates, but there is a potential for loss of critical institutional knowledge as key staff members retire without hiring people to replace them and the time to transfer the senior staff members' knowledge to junior personnel. This concern applies throughout the laboratory enterprise, from regional laboratories to ORD research facilities.

FRAMEWORK FOR ALIGNING THE LABORATORY ENTERPRISE WITH STRATEGIC AGENCY GOALS

Overall

The purpose of the analytic framework is to develop principles and guidance to ensure that the laboratories operate efficiently and effectively to advance the agency's goals. The laboratory enterprise makes up a subset of EPA's broad array of science-related activities (described in Chapter 1). Its primary function is to serve the program and regional offices by supporting the agency's strategic goals and overall mission. EPA seeks to ensure that this function is provided through the process shown in Figure 2-1, which includes planning and resource allocation, implementation of laboratory activities, production of outputs and outcomes, and evaluation and assessment for planning and implementation—all in the service of programmatic activities reflecting the strategic goals.

Figure 2-1 depicts the iterative nature of the process. Every 5 years, the agency develops a strategic plan that encompasses the five overall goals (1) of the agency and each program office. Those overall goals drive the activities and goals of the laboratory enterprise (2), which consists of the ORD laboratories and centers, the regional office laboratories, and the program office laboratories. All the laboratories support the strategic goals by implementing a variety of short-term and long-term activities (3) that are selected in consultation with national program office and regional managers. Implementation of the activities is monitored (sometimes by both external and internal reviewers) and adjusted. Implementation yields outputs and short-term or intermediate outcomes (4) delivered to the programs and regions. The products of the laboratory enterprise not only support programmatic decisions and actions but may contribute to long-term outcomes (5), such as improvements in public and ecosystem health, clean air, and increased climate stability.

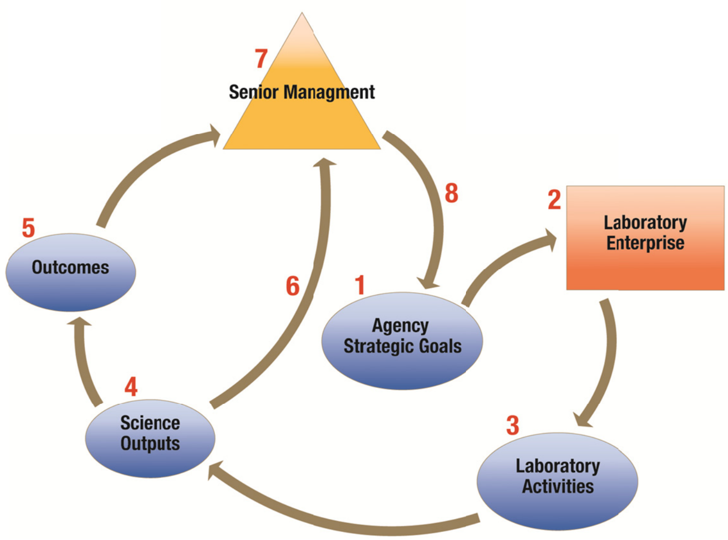

FIGURE 2-1 The overall process, in generalized form, that connects EPA strategic goals with the laboratory enterprise. See text for explanation of the numbers. Source: Adapted from NRC (2008).

The outputs and outcomes of the laboratory enterprise are reported to senior EPA management, including leaders in the program and regional offices, depending on the connection of the research activities to a given issue, and are used to inform decision-making (7). Assessment of the results informs annual cycles of planning and budgeting for laboratory activities. It also informs the 5-year revisions of the agency's strategic plan, including updates that reflect new science, new issues, and new priorities (8).

The portion of the process that is of most immediate concern to the committee's statement of task is represented as a conceptual analytic decision framework, shown in Figure 2-2. The figure focuses on the planning and budgeting, implementation, and assessment of outputs and outcomes for the laboratory enterprise and more particularly for the three main laboratory components of the enterprise. As explained above, the three laboratory components serve the agency's mission in different ways and, although the criteria of efficiency and effectiveness apply to each, they may be applied differently for each. The three components all serve the agency's strategic goals, and all need to be measured in the end by their contributions to reaching the goals. Moreover, although they can be broadly distinguished, some functions of the different types of laboratories are overlapping. For example, research by an ORD laboratory may be necessary to develop a method that a program or regional laboratory can use in carrying out a successful enforcement investigation. Some level of information-sharing and coordination within the laboratory enterprise is essential for its overall success.

We define the analytic framework further below for each of the three laboratory components and distinguish where the processes differ. Recommendations for optimizing laboratory performance within the framework are presented in later chapters.

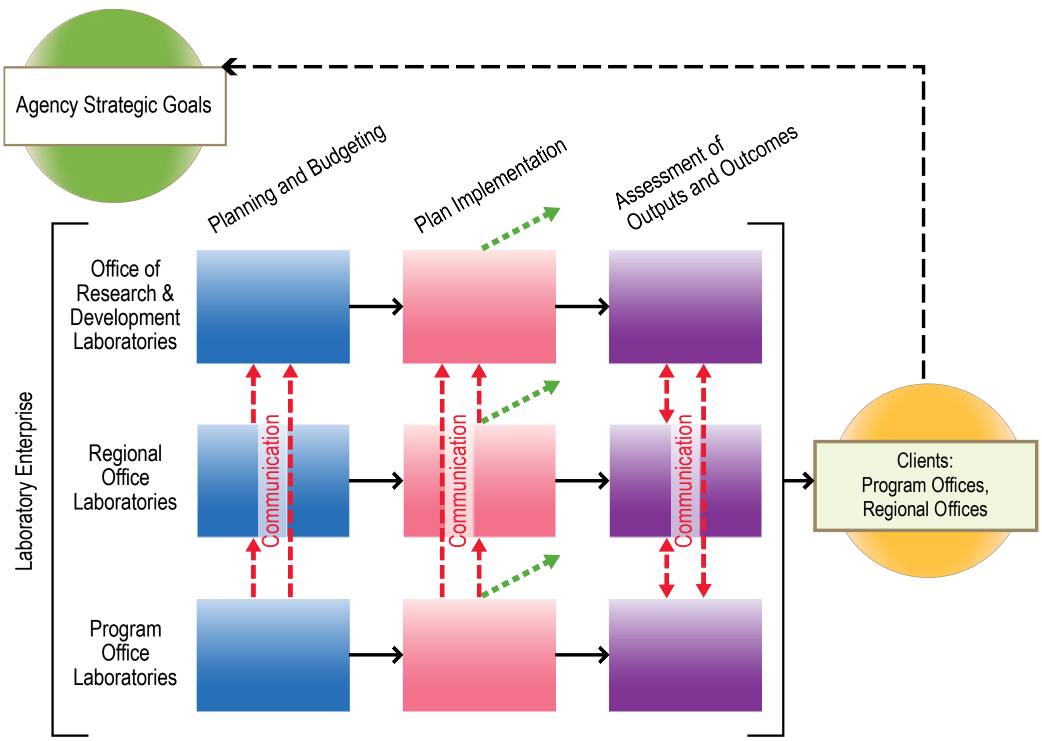

FIGURE 2-2 The portion of the overall process shown in Figure 2-1 that focuses on the role of the laboratory enterprise. Three major steps are shown: planning and budgeting, implementation, and assessment of outputs and outcomes. Those apply to all three of the components of the laboratory enterprise. The dashed red arrows indicate internal communication among laboratory components, and the dotted green arrows indicate where the laboratories would benefit from external communication with other scientific entities. Both kinds of communication and coordination need to be enhanced (see Chapter 4). Other communication directions are not intended to be prohibited. Note: PO = program office; RO = regional office.

Framework for Office of Research and Development Laboratories

The application of the framework to ORD is expanded and depicted in Figure 2-3, which includes the three steps—planning and budgeting, implementation, and evaluation of outputs and outcomes. Specific criteria are included at appropriate places in the framework to address and maximize efficiency and effectiveness (see Chapter 4). The ORD element of the laboratory enterprise is perhaps the most complicated but has the most advanced planning process. In 2010, ORD began the process of realigning its research efforts with the concepts of sustainability. That effort involved the reduction of 13 research programs in ORD into six more integrated national programs (Anastas 2012).

An ORD 4-year strategic research plan is developed for each national research programs developed collaboratively to link agency goals to ORD goals and objectives. That is necessary because agency goals are not specific enough to inform or direct the workplans of the ORD national research programs. The plans are developed by ORD's national program directors (NPDs) in consultation with ORD senior management.[1] NPDs consult with the laboratory directors, but the issues driving the strategic plan come mostly from the NPDs in consultation with the program offices and regions. Annual project planning uses a matrix management approach whereby the NPDs and laboratory directors collectively determine priorities and how work will be done. Annual congressional appropriation funds received by ORD laboratories and programs contribute to determining the planning process. The matrix planning paradigm has been successfully implemented in recent years, but the overall process could be enhanced if the criteria for assessing efficiency and effectiveness were addressed systematically as discussed in Chapter 4.

The process for developing the budgets (for the executive branch's budget request to Congress) is also collaborative, but inasmuch as it is done for future fiscal years, budgeting is not coupled directly to annual operational planning, which focuses on the current fiscal year.

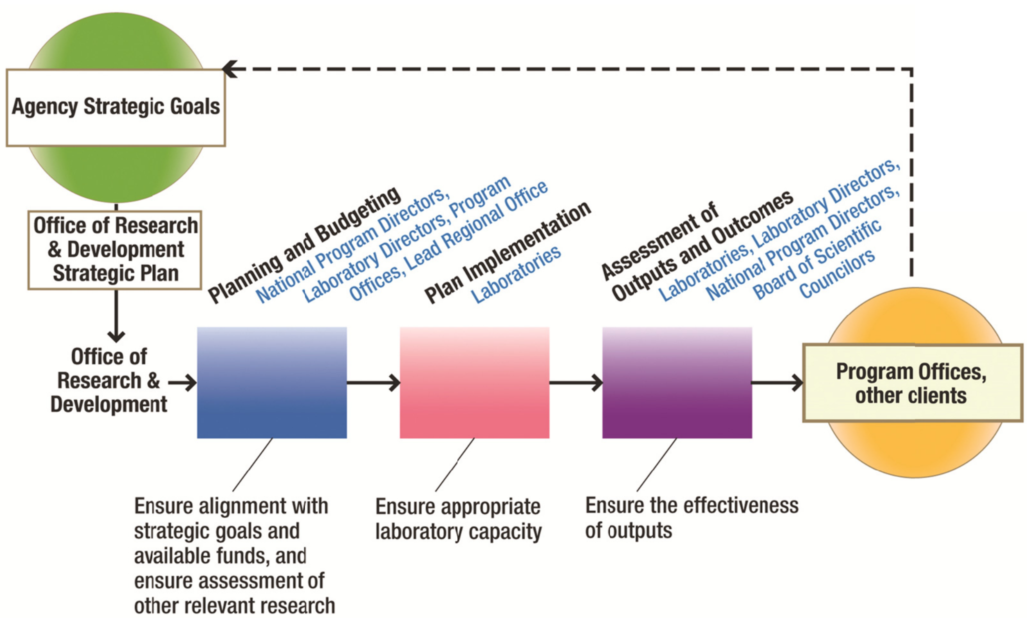

FIGURE 2-3 Aligning agency strategic goals to the ORD portion of the laboratory enterprise. Note: NPD = national program director; LD = laboratory director; PO = program office; RO = regional office; BOSC = Board of Scientific Councilors.

[1]Each of ORD's six national research programs is led by an NPD. The NPDs are responsible for ensuring that the science conducted is relevant and of high quality. (EPA 2014c)

Once research goals are established, ORD implements programs through a variety of short-term and long-term research activities. The activities result in short-term advances and outcomes and eventually in longer-term environmental benefits. Ideally, effectiveness and efficiency can be optimized by considering the specific criteria discussed earlier in this chapter and addressed in Chapter 4. Short-term outputs of research can be evaluated for efficiency (for example, Was it done on time, on budget? Did the research unknowingly duplicate other scientific efforts?) and effectiveness (for example, Are results of sufficient quality to be useful? Does the research address the problem but lack suitability for implementation?) and then be reported to the NPDs and the senior management of the program offices depending on the connection of the research activities to given program office issues. The outputs and outcomes are shared with the program offices and the senior administration at headquarters to inform decision-making over the next annual cycle. In 4-year time horizons, the strategic plans are altered to reflect new science, new issues, and new priorities.

Regional Office Laboratories

The application of the framework for assessing regional office laboratories is different from that for assessing ORD laboratories owing to their mission of applying science to regulatory enforcement. The approach is outlined in Figure 2-4. Regional office laboratories support primarily short-term objectives related to specific enforcement actions in a region or projects developed specifically to meet the needs of the region as designated by the regional administrator. They are generally not involved in exploratory science and are typically restricted to using narrowly-defined procedures and strict quality-assurance and quality-control practices to ensure the reliability and acceptability of delivered data. The current structure provides flexibility and support for a regional administrator to undertake projects that are seen as important to the region.

However, this approach for regional office laboratories may not provide maximally efficient and effective laboratory capabilities in that some of the facilities will be relatively small in terms of staff and equipment. For recommendations that address this, see Chapters 3 and 4.

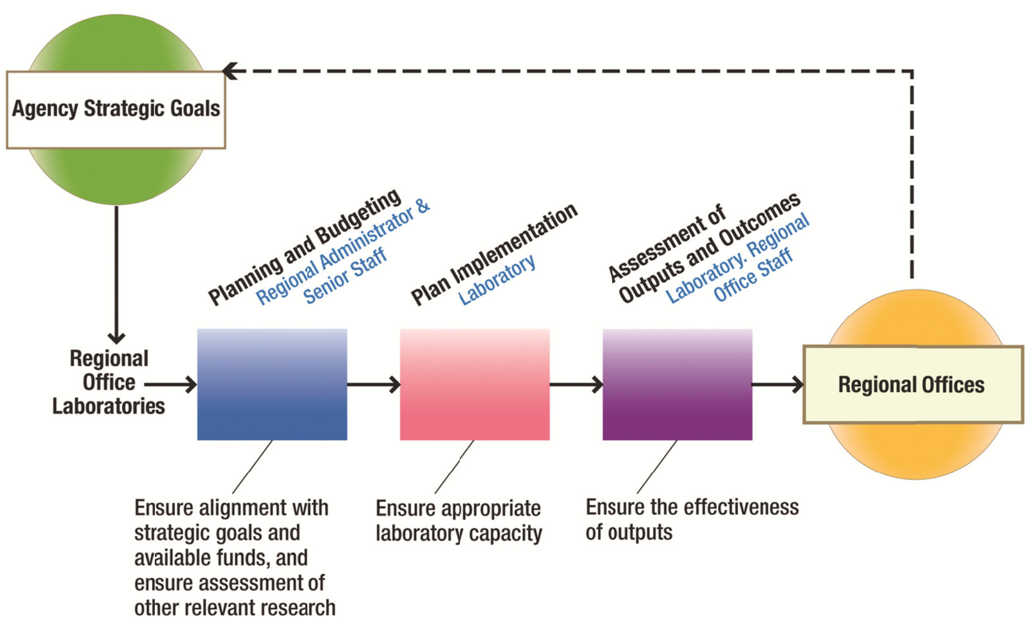

FIGURE 2-4 Aligning agency strategic goals with the regional office laboratories. Note: RA = regional administrator; RO = regional office.

Program Office Laboratories

Program offices maintain laboratories that directly support regulatory implementation, compliance, and enforcement efforts at the national level. There are eight such laboratories (two of which are referred to as centers). For example, they include a national enforcement and investigations laboratory in the Office of Enforcement and Compliance Assurance; two laboratories in the Office of Air and Radiation, of which one is devoted to testing of vehicle emissions, fuel economy, and transportation fuels and the other to assessing radiation risks; and laboratories in the Office of Chemical Safety and Pollution Prevention that support the agency's pesticide registration and enforcement program (see Chapter 1).

An analytic framework for the program laboratories appears in Figure 2-5. Unlike the ORD and regional laboratories, these laboratories are under the direct control of the managers of the national program offices responsible for implementing and enforcing EPA's regulatory programs. They follow the same sequence of planning, implementation, assessment, and feedback as EPA's other laboratories, but the work of each program office laboratory is focused on the needs of one program client, and they are managed as part of that client. Integration of the program laboratories in the management processes of their program client will likely facilitate alignment with program needs and strategic goals. Although location of these laboratories in the program offices may simplify some management issues, there is a need to enhance information-sharing and coordinating with other components of the laboratory enterprise (see Chapter 4).

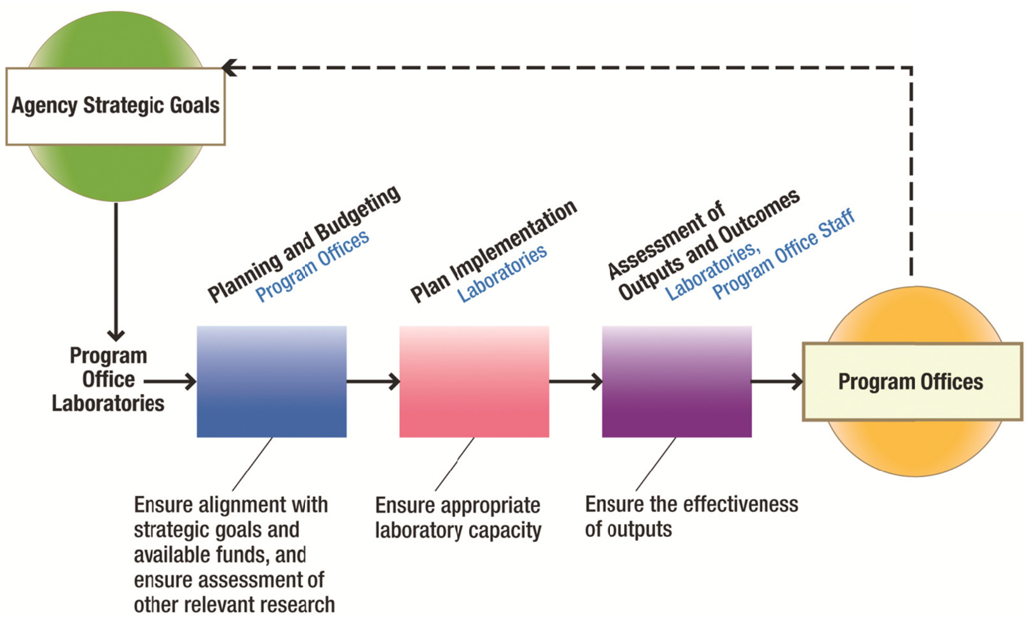

FIGURE 2-5 Aligning agency strategic goals with the program office laboratories. Note: PO = program office.

3

Laboratory Science Capabilities

OVERVIEW OF THE CHAPTER

The Environmental Protection Agency (EPA) laboratory enterprise has been defined or established not as an organizational entity but as an amalgamation of three distinct laboratory types that have distinct missions, drivers, and personnel: Office of Research and Development (ORD) laboratories, program office laboratories, and regional office laboratories.

The critical components of the laboratories, regardless of type, are the people, the physical facilities, and the equipment. This chapter focuses on the workforce and equipment. Physical facilities are being looked at in a separate activity (see Chapter 1). And the chapter does not attempt to assess the extent to which the functions and capabilities of EPA laboratories are synergistic or duplicative; this was not in the committee's charge.

The importance of the quality and expertise of people in an organization cannot be overemphasized (NRC 2012b). The most reliable predictor of research and development (R&D) performance is the quality of the workforce. Of special importance for many R&D organizations is the presence of people who have substantial creative, scientific, and technical capabilities. An effective organization enables its staff to capture new skills that are required for a set of tasks while over the long term building the network required to make team members effective participants in organizationwide efforts to achieve overall goals. The workforce should also be nimble and adaptable so that it can address new challenges. The creation of such capabilities requires diversity of personnel expertise and work experience.

A snapshot of the scientific and technical disciplines of the scientists and engineers involved in the three types of EPA laboratories was provided by EPA and are what would be expected for the premier environmental and health regulatory agency that is EPA. An analysis of the current workforce disciplines and the ones that EPA believes that it will need in the future was initiated recently, and results are being implemented. Key tools that would provide EPA with flexibility with regard to achieving workforce expertise needed in the future are its postdoctoral program, its Title 42 Authority, and training grants. Finally, managing and acquiring equipment throughout the EPA laboratory system is considered.

SUMMARY PRINCIPLES

The 2012 National Research Council report *Best Practices in Assessment of Research and Development Organizations* (NRC 2012b) provides a list of attributes that characterize an effective R&D organization and are considered to be good indicators of the eventual impact and relevance of the organization and the R&D that it performs (see Appendix D). Using those attributes, the present committee developed the following principles for the effective and efficient management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals:

> **Summary Principle 1:** Every science institution is more effective if it has a vision of how its scientists, technicians, and other professionals can best contribute to the organization's mission and goals.

Summary Principle 2: Essential laboratory capabilities are the ones that are relevant to the current mission and the ones that anticipate future mission needs. Priorities for laboratory capabilities should focus on work that is central to the agency's mission rather than on small peripheral efforts.

Summary Principle 3: Laboratories should avoid internal redundancy or duplication of capabilities that are readily available externally.

Summary Principle 4: Recruiting, developing, and retaining an outstanding, committed scientific and technical workforce is crucial for maintaining outstanding laboratory capabilities.

Summary Principle 5: State-of-the-art facilities and equipment are essential if a laboratory enterprise is to be able to meet current and future mission needs.

Summary Principle 6: Effective management and appropriate flexibility enable an efficient and effective laboratory enterprise.

Summary Principle 7: Communication and coordination among the laboratories within an organization are essential for efficiency and effectiveness.

Summary Principle 8: Outstanding research and other science-related activities are the foundation for meeting current and future mission needs and for sustaining leadership in environmental science and applied research.

Summary Principle 9: A strong linkage to universities, industry, research institutions, and other federal and state government organizations enhances the laboratory enterprise and prepares it for the future.

THE ENVIRONMENTAL PROTECTION AGENCY'S LABORATORY WORKFORCE: SNAPSHOT OF CURRENT SCIENTIFIC AND TECHNICAL WORKFORCE

As indicated in summary principle 4, recruiting, developing, and retaining an outstanding workforce is one of the keys to a successful laboratory enterprise. EPA indicated that 2,261 EPA personnel and 1,370 non-EPA personnel were working in agency laboratory facilities. Those EPA laboratory personnel made up 14.6% of all the agency's personnel in 2013. Of the 2,261 EPA laboratory personnel, about 83% (1,871) were working in science and technology disciplines; the remaining 17% were administrative and legal personnel (see Figure 3-1). Of the 1,370 nonfederal laboratory personnel, about 74% (1,007) were working in science and technology disciplines (see Figure 3-2). The three largest components of the federal laboratory workforce were Biology & Health Sciences (22.3%), Chemistry (20.9%), and Engineering (13.1%); the three largest components of the nonfederal laboratory workforce were Science Support (34.7%), Chemistry (22.2%), and Information Science/Technology/Management (15.1%).

Budgetary constraints over the past few years have made it difficult for EPA to hire people with the necessary skills for addressing current and emerging complex problems. To realign its workforce in the midst of limited resources, EPA announced the availability of Voluntary Early Retirement Authority (VERA) and Voluntary Separation Incentive Payment (VSIP) initiatives in December 2013.[1] The VERA process allows federal agencies to increase the number of employees who are eligible for retirement by lowering the age and service requirements temporarily. The VSIP process allows lump-sum payments to

[1]For information on VERA, see http://www.opm.gov/policy-data-oversight/workforce-restructuring/voluntary-early-retirement-authority/. For information on VSIP, see http://www.opm.gov/policy-data-oversight/workforce-restructuring/voluntary-separation-incentive-payments/.

be given to employees, who are in surplus positions or have skills that are no longer needed in the workforce, to induce them to separate from the government. Through the VERA/VSIP offering, EPA sought to enable the agency to reshape the workforce, build diversity, bring in new talent and move toward new models of performing work.

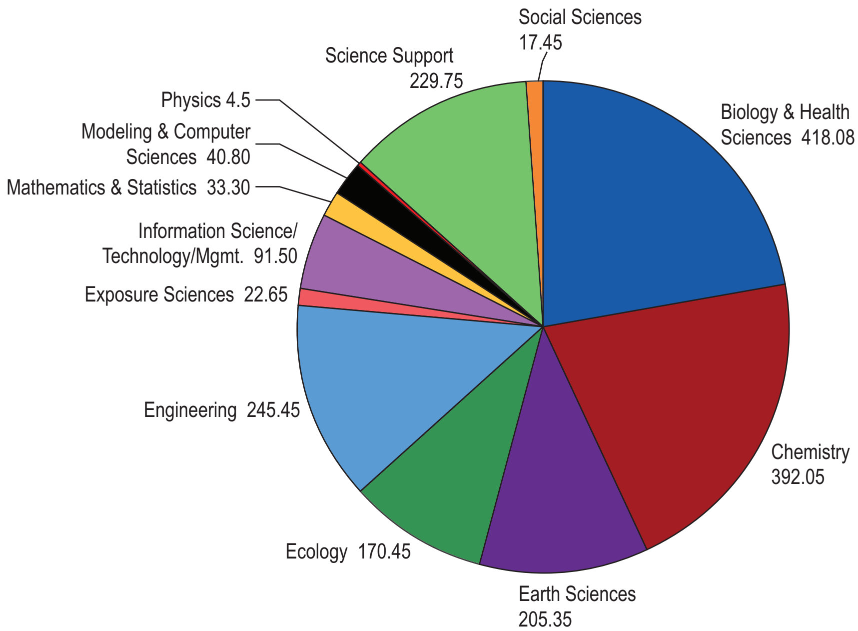

FIGURE 3-1 Total federal EPA-laboratory employees in all EPA laboratories. Numbers are numbers of FTE laboratory personnel in the identified disciplines. Source: EPA 2014d.

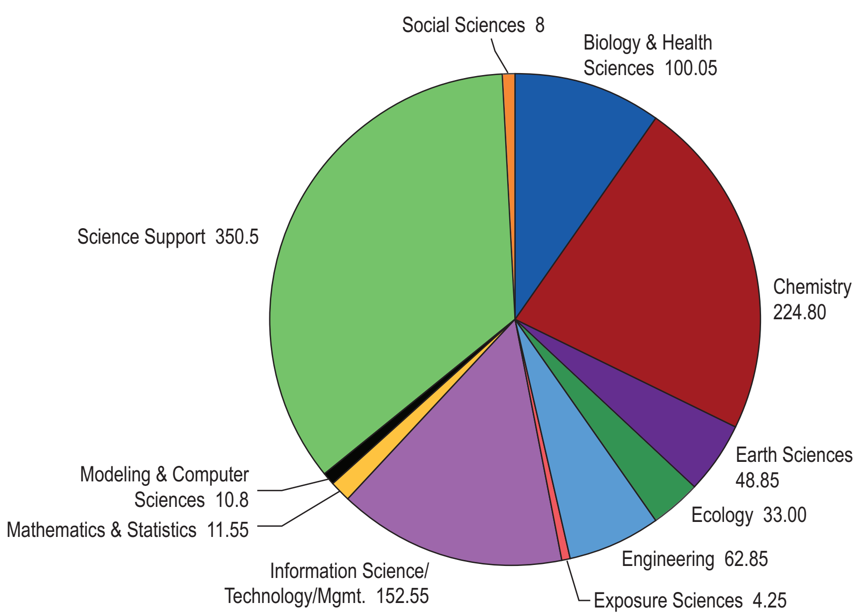

FIGURE 3-2 Total nonfederal EPA-laboratory employees. Numbers are numbers of FTE laboratory personnel in the identified disciplines. Source: EPA 2014d.

Instead of using VERA/VSIP agencywide, EPA invited offices to develop their own proposals for using the process. For example, laboratory personnel were addressed by a VERA/VSIP initiative of the Office of Chemical Safety and Pollution to aid in reducing the number of laboratories in its Biological Economic Analysis Division from 4 to 2. The Environmental Chemistry Laboratory of Prevention at Bay St. Louis, MS was closed because its primary work on dioxin analysis is no longer a priority. Also, the Microarray Research Laboratory located in Fort Meade, MD was closed because the research conducted at the laboratory has been completed (EPA 2014e).

Also as part of this VERSA/VSIP effort, ORD undertook a planning activity to identify gaps within its scientific workforce and approaches for addressing the gaps.

> "Approximately 150 scientific disciplines representing the relevant specific skills and expertise in 11 broad workforce groups (e.g., biology, chemistry, engineering, and modeling and computer science) were identified to characterize both ORD's current workforce as well as the skills that will be needed to fulfill ORD's research commitments over the next three to five years. . . . A complete strategy for addressing the gaps is under development." (EPA 2014e)

The committee has not reviewed the process by which EPA conducted its workforce evaluation, the timeframe needed to complete the analysis, or the outcome. Going forward, it will be important for EPA to complete such workforce analyses in a timely and transparent manner to enable planning, recruiting, and hiring to be successful.

EPA should continue and strengthen its characterization and evaluation of its laboratory workforce, establishing a defined timeline and being transparent in its processes for internal and external audiences. ***(Recommendation 3-1)***

EPA should initiate or complete the development of a strategy for periodically addressing the composition of the workforce in the ORD laboratories, the regional office laboratories, and the program office laboratories, particularly after completion of the Voluntary Separation Incentive Payments/Voluntary Early Retirement Authority actions in 2014. The analysis should include an inventory of skills and training and demographic analysis (for example, projected retirements over the next 5 years) for strategic planning for the future. This information is essential for making sensible decisions in hiring, future reassignments, and offers of voluntary retirements. ***(Recommendation 3-2)***

EPA should continue to cultivate an interdisciplinary scientific workforce at all levels of expertise throughout the laboratory enterprise that can engage in high-quality, collaborative, science activities aimed at transdisciplinary challenges. ***(Recommendation 3-3)***

TOOLS FOR ACHIEVING WORKFORCE EXPERTISE

The committee did not review EPA's recruitment or retention practices; such practices have been reviewed and recommended elsewhere (see, for example, NRC 2000, 2010). The committee focuses on the use of these recommended practices for its laboratory personnel to encourage strategic hiring and be more effective in filling vacant positions.

To "sustain leadership capabilities of its laboratory enterprise for environmental science and research", per this committee's Statement of Task (see Appendix A) EPA will need individuals with excellent, high-quality expertise in science, engineering, and other related fields. To the extent practicable under budget constraints, three tools that would provide EPA flexibility in achieving continuing workforce excellence are the agency's training grant and fellowships programs, postdoctoral program, and Title 42 program**.** An important component of implementing each of these tools is periodic independent review to assess whether the efforts are meeting their intended objectives.

Training Grants and Fellowships

Building an EPA workforce for the future requires an adequate pipeline of scientists and engineers trained for and experienced in the work that EPA must do to satisfy its mission and reach its goals. Training grants offer the opportunity for gathering information or advancing the state of knowledge as opposed to solving an environmental problem with an established method. Such programs train scientists in environmental fields and increase public understanding of relationships between the environmental and human health. For example, EPA has recently listed fields of interest to ORD for such training: toxicology, pharmacokinetics, carcinogenesis, environmental epidemiology and clinical research, biostatistics and modeling, sustainability and systems thinking, risk and exposure assessment, emission estimation, life-cycle analyses, and risk management and mitigation (EPA 2014f).

The committee notes that EPA recently issued a request for proposals for a cooperative training partnership in environmental health sciences research. The objective of such a training partnership is aligned with the committee recommendation for enhancing and ensuring a pipeline of students trained in environmental disciplines needed for EPA's future workforce (EPA 2014f). **EPA should develop relationships with community colleges and universities to enable students to work in EPA laboratories as interns or student employees in an effort to develop future technicians and scientists who will conduct research and other laboratory functions related to EPA needs. *(Recommendation 3-4)***

EPA is offering Greater Research Opportunities (GRO) fellowships for undergraduate environmental study (EPA 2014g). In the past, it also offered Science to Achieve Results (STAR) graduate fellowships to support master's and doctoral candidates in environmental studies. However, STAR fellowships are not being offered in 2014 (EPA 2014h) the STAR graduate fellowship program is planned to be transferred to the National Science Foundation (NSF). The change in the home of the program fails to recognize the differences in training between an EPA fellowship program focused on environmental science and technology and a basic Earth or physical science fellowship emphasized in NSF. **EPA should continue, enhance, and expand its student training grant programs, such as GRO. The STAR fellowship program should be reinstated in EPA to support the research programs specific to EPA's mission and goals. *(Recommendation 3-5)***

Postdoctoral Program

By using the federal postdoctoral research program,[2] EPA can use early career scientists to address critical short-term research problems. More than 300 postdoctoral researchers participated in the program in ORD in 2001–2012 (see Figure 3-3). Young scientists—trained in the application of advanced and diverse research approaches—help to provide a scientific foundation of EPA's decision-making. The program also provides postdoctoral scientists with a deeper understanding that may enhance their research futures, wherever their next professional positions may be. Under the guidance of mentors, the postdoctoral scientists gain experience in multiple facets of mission-driven applied research in the federal government. **EPA should continue its planned hiring of postdoctoral researchers by ORD and expand it to other types of laboratories as appropriate. *(Recommendation 3-6)***

Title 42 Program

EPA needs tools for attracting and hiring the highest-quality scientists and engineers now and will in the future if it is to protect health and the environment effectively and efficiently. Title 42 authority was

[2]The Schedule A, 213.3102(r) excepted service appointing authority (called R authority) can be used to fill positions in a variety of programs, including fellowship, internships, and residencies. Appointments under the authority may not exceed 4 years. Excepted service authorities enable agencies to hire when it is not feasible to use traditional hiring procedures.

granted to EPA in 2006. Its goal is to recruit and retain world-class scientists and engineers who can strengthen EPA's research and improve the application of science to address its regulatory responsibilities. The program is also aimed at addressing emerging research needs and filling critical gaps in EPA research capacity.

A 2010 National Research Council report that reviewed the initial years of EPA's use of Title 42 authority found that the program was working well and that the appointments had the important effect of "strengthening of state-of-the-art science in fields that are primary to the agency's mission to protect health and the environment" (NRC 2010, p.22). The report recommended that permanent Title 42 authority be granted to EPA, that the EPA Board of Scientific Counselors or Scientific Advisory Board (SAB) be asked to review the Title 42 program every 5 years to ensure that it is being used for the intended purposes, and that EPA be granted expanded authority to define the number of Title 42 positions on the basis of its programmatic needs and available budget. The report also noted that the use of Title 42 authority should continue to be restricted to recruiting and retaining highly qualified scientists and engineers.

In the FY 2014 appropriation, Congress provides the EPA administrator with the authority, for FY 2006–2015 and after consultation with the Office of Personnel Management, to employ up to 50 persons at any one time in ORD under the authority provided in 42 USC 209. (For FY 2009–2014, ORD had a ceiling of 30 persons.) The FY 2015 presidential budget request proposes extending ORD's authority through FY 2017 with no limit on the number of persons.

The committee agrees with previous expert panels and committees that a science and engineering workforce that is capable of performing and conducting research at the highest level is essential for EPA if it is to protect public health and the environment. The committee notes that the number of Title 42 appointments is not limited in several other federal agencies that fill scientific positions by using Title 42 authority. According to the US Government Accountability Office, in 2010, the Centers for Disease Control and Prevention had 929 Title 42 employees, the US Food and Drug Administration had 862, and the National Institutes of Health had 4,879 (GAO, 2012. The numbers of Title 42 appointments in those agencies are substantially larger than the number in EPA.

The committee agrees with the 2010 National Research Council report (NRC 2010), EPA should be granted permanent Title 42 authority and the expanded authority to define the number of Title 42 positions on the basis of its programmatic needs and available budget. In addition, EPA should use an independent body to review the Title 42 program every 5 years to ensure that it is being used for its intended purposes. ***(Recommendation 3-7)***

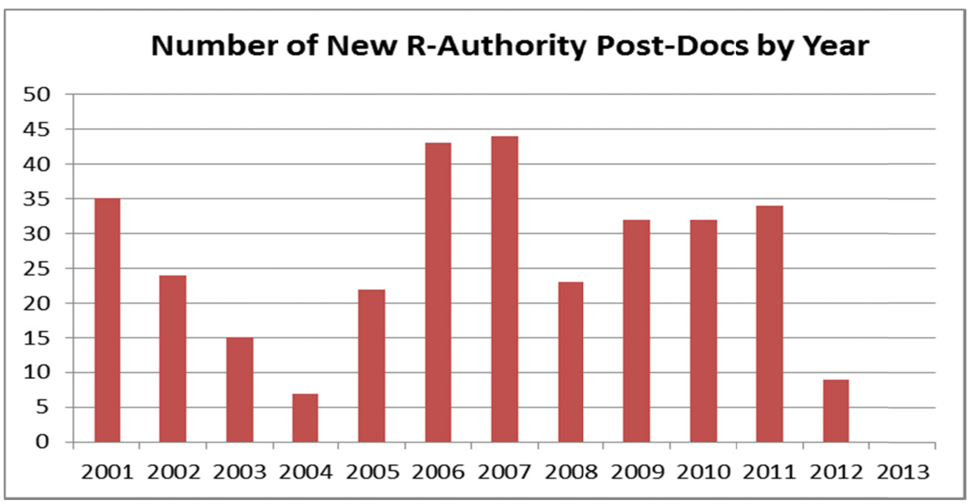

FIGURE 3-3 Number of new postdoctoral scientists in EPA ORD by year, hired under R authority. No new postdoctoral scientists were hired in 2013. Source: EPA 2014i).

TOOLS FOR MEETING STRATEGIC SCIENTIFIC AND TECHNICAL GOALS

As indicated in the National Research Council report *Science for Environmental Protection* (NRC 2012a), because "environmental problems are increasingly interconnected, EPA can no longer address one environmental hazard at a time without considering how it interacts with, is influenced by, and influences other aspects of the environment" (p. 152). That report also stated that "systems-level tools and expertise are needed for the systematic analysis of health, environmental, social, and economic implications of individual decisions."(p. 110)

A 2012 report from EPA's SAB found that science integration practices vary within the agency. Some managers actively promote science integration, but more could be done in most program and regional offices. The SAB also found that EPA has not developed a coordinated human-resources strategy for building the necessary science base for ORD and the rest of the agency (EPASAB 2012).

It is important for EPA to conduct its hiring in a strategic manner that seeks to anticipate needs. It is also important to develop and retain staff members who are experienced in interdisciplinary work and effective in leading and supporting teams. EPA needs a leadership-development program to ensure that early-career and midcareer staff can attain the leadership skills that will be needed as key team leaders and project leaders retire.

For efficiency and effectiveness, members of the EPA workforce must cover a broad array of disciplines, work effectively in teams, and have the flexibility to address both continuing projects and emergencies that need EPA expertise. In line with summary principle 7, EPA needs to create tools for communication to enable leaders and staff in all the various laboratories to be aware of the scientific expertise, available laboratory equipment, and project goals and approaches in the entire laboratory enterprise. Easy access to that information will enhance the flexibility and nimbleness of scientists and engineers who have the ability to work in interdisciplinary teams. The agency has risen to such challenges in the past, but it needs to establish processes by which such approaches can be routine.[3] **EPA is encouraged to continue taking steps to improve the transparency and cross-agency awareness of capabilities through enhanced communication regarding scientific and engineering staff expertise and laboratory equipment.** ***(Recommendation 3-8)***

LABORATORY EQUIPMENT

The quality of facilities and equipment, including buildings and capital equipment, is an important element of the laboratory enterprise; the lack of infrastructure can stand in the way of even the highest-quality workforce (NRC 2012b). The committee does not have information on facilities and operating costs; that will come from EPA's analysis of the current portfolio of laboratory facilities (see Chapter 1). Laboratory equipment is the main focus of our recommendations.

As summary principle 5 indicates, state-of-the-art facilities and equipment are essential for an outstanding laboratory enterprise to be able to meet current and future mission needs. In response to the committee's request, EPA provided descriptions of various processes for managing and acquiring laboratory equipment (see Box 3-1).

ORD, program, and regional laboratories have various processes for managing and acquiring laboratory equipment, but the processes and inventory tools are not connected throughout EPA.

EPA should link inventory of equipment over $500,000 in all laboratories, without regard to mission, to an agencywide accessible process. Before investment in large capital equipment, laboratory equipment in other parts of EPA, other agencies, and universities that could be available for shared use should be explored. ***(Recommendation 3-9)***

[3]One such example is an exercise conducted in 2012 by EPA Regions 4, 5, and 6 and other federal agencies to facilitate the interactions of three national laboratory networks in the face of a combined public-health and environmental emergency. The three networks are the Environmental Response Laboratory Network, the Laboratory Response Network, and the Food Emergency Response Network (Hanley 2012).

EPA should continue taking steps to improve the transparency and agencywide awareness of all its laboratory science capabilities. ***(Recommendation 3-10).***

BOX 3-1 EPA Processes for Managing and Acquiring Laboratory Equipment

Office of Research and Development Laboratory Equipment

The Office of Research and Development (ORD) capital-equipment management process provides a strategy whereby scientific equipment needs are subjected to identification, priority-setting, funding, and procurement. Each year, ORD organizations that have laboratory capabilities develop a priority list of capital-equipment needs with detailed justifications for each item. Priority lists are submitted to the ORD Capital Equipment Committee (CEC). The CEC then submits the lists to the ORD assistant administrator, who provides final approval of all capital equipment.

Program Laboratory Equipment

The Office of Air and Radiation's (OAR's) National Vehicle & Fuel Emissions Laboratory has several venues in which capital scientific-testing equipment needs are identified and then incorporated into OAR's Office of Transportation and Air Quality's (OTAQ's) budgeting process, which balances equipment and testing investments against all other OTAQ programmatic priorities.

For OAR's National Analytical Radiation Environmental Laboratory NAREL, laboratory improvements and investments for capital equipment are identified during the annual planning and priority-setting process of OAR's Office of Radiation and Indoor Air. NAREL reviews the current capital-equipment status—taking into account programmatic needs, new technology options, and the age and reliability of existing equipment—and determines priorities for requesting new capital equipment. Decisions are made on where best to invest resources on the basis of programmatic needs.

The National Enforcement Investigations Center maintains an inventory of its scientific instrumentation in addition to the official agency property-management system. Every year, the branches update the list during a discussion of availability of new instrumentation and how it could be used to meet the agency's enforcement needs. A priority list of potential purchases is developed. As funding becomes available through the year, instrumentation on the list is purchased.

The Office of Water does not have a budget specifically for laboratory capital equipment, nor does it have a unique or independent process for capital-equipment requests. Such purchases are funded out of the same budget that funds its extramural programmatic support, and the merits of requests for those purchases are judged in the light of competing requests for funds. Equipment needs are developed by the project officers responsible for the oversight of the laboratory work.

The Office of Chemical Safety and Pollution Prevention's (OCSPP's) management reviews laboratory operating needs annually. All proposals for laboratory capital-equipment expenditures are linked to the OCSPP priorities and workplan. The purchase of laboratory capital equipment is intended to allow OCSPP to meet programmatic needs, support environmental analyses, and provide direct technical support for states, tribal entities, other federal agencies, and academe. Temporary personnel assignments through the Intergovernmental Personnel Act and interagency agreements foster sharing of facilities and equipment with partner agencies.

Regional Office Laboratory Equipment

Funds for capital equipment are distributed to the regions on the basis of their sizes (in full-time equivalents) and numbers of Superfund sites. Each regional laboratory develops a priority list of new equipment needs annually.

The 10 regional laboratories exchange information on new capabilities (new instruments and methods) through monthly conference calls among laboratory directors and calls among members of the laboratory technical information group for organic, inorganic, and microbiology. Before purchasing a new high-cost item, a laboratory evaluates whether its program need can be satisfied through an existing inventory or assistance elsewhere in the regional laboratory network. A laboratory can request assistance as needed from regions that have developed a particular capability or have available instrumentation and training or troubleshooting for the type of instrument in question.

Source: EPA 2014i.

4

Management

CHAPTER INTRODUCTION

The National Research Council and other entities have previously studied components of the Environmental Protection Agency (EPA) laboratory enterprise. Their studies have resulted in a number of important recommendations to increase the efficiency and effectiveness of EPA's research capabilities. The focus of those studies and recommendations has been, for the most part, on the Office of Research and Development (ORD) laboratories. EPA has generally been responsive to the recommendations and has improved the management of ORD. One example is the Pathfinder Innovation Project, an internal competition to engage workers with release time to generate new ideas of high benefit and high leverage. Another example is the designation of national program directors to improve alignment of the work of ORD laboratories with program office needs.[1] (See Appendix D for a list of recommendations provided in previous reports.)

As discussed in previous chapters, however, ORD is only one component, albeit an important one, of the laboratory enterprise. More important for present purposes, the other components—the regional office laboratories and program office laboratories—are not mini-ORD laboratories. They generally do different types of work; ORD focuses more on basic and applied research whereas program office laboratories and regional office laboratories focus more on technical support and analytic services. The various components typically work on different timeframes; ORD may undertake research with a 5-year view whereas a regional office laboratory might need an answer for a cleanup facility extremely quickly and a program office laboratory may be engaged in technical projects that span a couple of years. As a result of their different tasks, the various laboratories need different types of scientific and technical expertise, and the various components report to different managers and policy officials—ORD laboratories report to the ORD assistant administrator, each regional office laboratory reports to its regional administrator, and each program office laboratory reports through its program office to its program office assistant administrator.

One consequence of those differences is that the previous recommendations for the ORD laboratories cannot simply be applied to the laboratory enterprise as a whole. Of greater importance is the fact that the "enterprise as a whole" consists of diverse types of entities that have different immediate priorities, are typically in different places, and are required to do different things. EPA's laboratory enterprise thus presents a management challenge. A cohesive entity with roughly comparable components near one another is one thing; EPA's laboratory enterprise, which is operated as a distributed network of laboratory facilities, is quite another. There are, to be sure, institutional links and substantial interactions among the various components of the enterprise, but, except for the concept, there appears to be little substance to the notion of a laboratory enterprise as a single entity. Indeed, the committee's requests for information and questions presented to EPA about its laboratory enterprise generally produced responses that focused on specific types of laboratories. The impression conveyed was that the laboratory enterprise consists of many different components, not a single functioning cohesive entity.

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[1] Each of ORD's six national research programs is led by a national program director. The directors are responsible for ensuring that the science conducted is relevant and of high quality (EPA 2014c).

It is not within the committee's statement of task to recommend reorganization or a consolidation of components of the enterprise. We do, however, recommend a reorientation and synchronization of the enterprise. Specifically, as discussed below, **EPA should approach management of its laboratory enterprise not so much as separate types of laboratories but as a system of the various laboratory efforts in EPA in which science and technical support activities are undertaken to support and advance the agency's mission–in other words, as an organized composition of diverse components. *(Recommendation 4-1)***

We discuss here first the need for a clear vision for the laboratory enterprise in accordance with summary principle 1: Every science institution is more effective if it has a vision of how its scientists, technicians, and other professionals can best contribute to the organization's mission and goals. Next, we address the management processes that would help to tie the enterprise together, focusing on planning and budgeting, implementation and allocation of resources, assessment, and communication within EPA. The chapter also provides the figures presented in Chapter 2 with additional questions (criteria) to illustrate kinds of information needed by the different types of labs to enhance effectiveness and efficiency at the enterprise level. The questions serve as an overview of the areas of improvement discussed in the chapter.

VISION

An important part of management is knowing what the entity is and what it is intended to do, and this is true of every scientific institution as well. *(Principle 4-1)* As noted above, the laboratory enterprise is currently more of a conglomeration than an organization. The amorphous nature of the enterprise is made all the more difficult for outsiders to grasp because the laboratories (be they ORD laboratories or regional office laboratories or program office laboratories) are only a part of the many and varied scientific efforts within and external to EPA that support its mission. Scientists, technicians, and engineers play important roles in the Office of the Administrator, in the program offices, and in the regional offices apart from the varied laboratories. That is all supplemented or complemented by the broad university research community around the country; by scientific research sponsored by many other parts of the federal government, its laboratories, and its research centers; by state agency laboratories; and by the private sector. As we discuss below, all those components (and the connections forged between them) contribute to EPA's ability to carry out its regulatory responsibilities on a day-to-day basis and to generate frontier knowledge that will contribute to fulfilling the EPA mission and to its future accomplishments.

The 2012 National Research Council report *Science for Environmental Protection: The Road Ahead* captured the role of science in EPA for the agency as a whole but did not single out the role of the laboratory enterprise in that effort. On the basis of our examination and review, we have concluded that EPA does not have a comprehensive justification or organizing vision for its current laboratory enterprise. For example, the EPA Web site includes a historical perspective: "Why Are Our Regional Offices and Laboratories Located Where They Are?" was written by Assistant EPA Historian Dennis Williams in 1993 in response to a request from the director of the EPA Office of Administration, John Chamberlin. The history (Williams 1993) concludes, "Since the early 1970s, some facilities have been closed and a few new ones have been opened, but the Laboratory system remains a product of the practical solutions developed by agency officials in the early 1970s to the problem of how to best use the facilities it inherited in December 1970." Today there may be sufficient reasons for the locations of most of the EPA laboratories. Some of those reasons are in part historical, others may have to do with the needs and priorities of the regions and the laboratories that support them, and still others may have to do with the needs and priorities of the programs.

We have not been tasked with sorting out the reasons for the locations of the laboratories or with recommending changes or consolidations. EPA has made substantial changes in its laboratory enterprise in the last decade and is examining ways to improve the efficiency and effectiveness of the enterprise further. In the process, EPA will probably consider such questions as these:

- Why is the laboratory enterprise structured (or not structured) as it is?
- Why do the components of the laboratory enterprise undertake the work they do?
- Most important, "how do the various elements of the EPA laboratory enterprise work together to achieve EPA's missions most effectively?

In light of those questions and related consolidation options, the committee notes that EPA laboratories in some parts of the country often support EPA missions in other parts of the country. EPA has several nationally and internationally well-regarded large fixed, laboratory facilities that would be expensive to move,[2] but EPA is generally noted for the scientific and technical expertise of its people, wherever they are. Accordingly, EPA can consider its laboratory enterprise primarily from the point of view of its capability to fulfill EPA missions overall.

Another important part of this process will be to articulate a vision for the EPA laboratory enterprise. That vision should strive to answer Director Chamberlin's question anew and address not only why the laboratories are where they are but how the various elements of the EPA laboratory enterprise work together to achieve EPA's missions. A vision for EPA's scientific endeavors will help EPA scientists, engineers, and technicians to see where they fit in, help the overall laboratory structure operate more effectively, and help to avoid unproductive efforts. As indicated in the summary principles presented in Chapter 3, every science institution is more effective if it has a vision of how its scientists, and technicians, and other professionals can best contribute to the organization's mission and goals. The EPA laboratory enterprise underpins the role of the agency as regulator, as setter of standards, and as a center of research related to its mission. It is wide-ranging and requires the insight of many scientific disciplines. We revisit those issues below. In any event, **EPA should develop a vision for its laboratory enterprise that maintains the strengths of the individual components but provides synergy through systematic collaboration and communication throughout the agency.** ***(Recommendation 4-2)***

MANAGEMENT PROCESSES

If EPA were to think of the laboratory enterprise as a system consisting of several different components organized to advance the mission of the agency, then there are a variety of management processes that could be strengthened to tie the components together without sacrificing the decided advantages that come from the in-depth experience, strong relationships, and proximity that has been the hallmark of the research, program office, and regional office laboratories. To better develop the effective and flexible management called for in summary principle 6, we look specifically at planning and budgeting, implementation and allocation of resources, assessment processes and, perhaps the most important, communications (summary principle 7).

Planning and Budgeting

As discussed below, EPA now uses a relatively well-developed strategic planning process; this extends to the separate components of the laboratory enterprise but not to the enterprise as a whole. Budgeting generally tracks the planning process for the agency and does not provide all the information that would be helpful in enhancing the efficiency and effectiveness of the laboratory enterprise.

[2]For example, the National Vehicle and Fuel Emissions Laboratory, in Ann Arbor, MI, is the primary EPA research laboratory used for fuel and emission testing. Its work supports the Office of Air and Radiation's efforts to establish and enforce emission standards for motor vehicles, engines, and fuels and to develop automotive technology (EPA 2013a).

Planning

On the basis of information provided by EPA, we understand that each ORD national program director, "building upon feedback received from ORD partners during the previous planning cycle, and the identification of new and emerging issues identified by the Laboratories and Centers, conducts a Portfolio Review" in the winter or spring of each year (EPA 2014j).[3] Thereafter, each research program conducts a program update with the appropriate program and regional offices.[4] In the July and August timeframe, further high-level discussions take place among officials of ORD, the program offices, and the regional offices to update the status of ORD research related to their programs, to confirm the research needs of the partners, and to receive approval for changes in research direction. In later summer and early September, ORD senior managers meet with the regional administrators and assistant administrators involved in each national program area to discuss the preceding year's accomplishments and priorities for the future. The information gathered through this process is formalized within the ORD research-management system, a database that contains a comprehensive view of ORD's current and planned research, which is used internally by ORD management and staff and can be accessed by program and regional offices throughout the agency.

The committee commends EPA for its progress in aligning the research efforts of the agency with the needs of its program and regional offices and ultimately with its strategic goals. However, more probably can and should be done. The materials that we have reviewed suggest that ORD, which has been through the most extensive external reviews, has implemented many of the reviewers' recommendations (see Appendix D), with the result that it appears to have a solid planning process. The committee strongly supports ORD's efforts to engage the program and regional offices as part of its annual planning process. We assume that the program office laboratories provide input to the program offices and the regional office laboratories provide input to the regional offices for the planning process. But the committee (and presumably other outsiders) does not know the extent of such involvement or whether it is ad hoc or systematic, because this part of the planning process is not transparent.[5] In addition, we commend Region 6 for its performance during the gulf spill and Region 2 in the New York City polychlorinated biphenyls schools crisis, but we have not seen how the experience of those emergencies or of other unexpected situations factors into the present year's or future years' planning.

Another gap that may exist (again, the committee does not know) is in the extent of consultation and coordination among the various regional office laboratories or program office laboratories for their own planning purposes. Many of the regional office laboratories undertake the same or similar activities. Although there are venues for consultation among them, such as annual meetings of the regional office laboratory directors, the committee was not able to assess the level of coordination flowing from them, including measures to improve the efficiency and effectiveness of the regional office laboratories as a group.

Systematic involvement of all the agency's laboratories in the planning process is far preferable to ad hoc connections and would probably yield a stronger and more efficient laboratory enterprise. (Princi-

[3]The purposes of the portfolio review, in which both the management and research staff of the laboratories and centers participate, are to review the status and progress of research projects and tasks, to highlight issues that affect completion or timeliness, to review ending tasks, and to discuss potential new projects or tasks with EPA partners and stakeholders.

[4]These updates occur at the staff level and include a review of and discussion about the status of products, discussion of issues or changes in research directions, documentation of partner comments on previously delivered products, and identification of new or emerging partner needs.

[5]The committee also does not know the extent to which the program office and regional office laboratories have input into the planning processes of their chains of command whereby any new needs of the program offices or regional offices are filtered down to the work plans of the laboratories or how elimination of a laboratory-related function is communicated to the laboratories and implemented by them. In fact, what we have been provided suggests an expectation in both the program office and regional office laboratories that business will proceed as it has in prior years.

ple 4-2) At the very least, it would bring into the planning process each of the various contributors to the end result, so they would be cognizant of how their efforts lay the foundation for or build on work done by others to achieve the optimal performance of the agency in moving toward its strategic goals.[6] And systematic involvement of the laboratories in the planning process would make it evident to EPA senior managers where there may be duplicative or overlapping resources that can be eliminated or redirected to other, more pressing needs of EPA. **EPA should ensure that its laboratory planning process includes cross–regional office and cross–program office laboratory input and that it is more transparent within the agency and to outsiders. *(Recommendation 4-3)***

Budgeting

In moving toward more efficient and effective management of its laboratory enterprise, EPA may be hampered by a lack of critical information related to its laboratories. Specifically, during the committee's deliberations, it was difficult to get a handle on the amount of funds attributable to the laboratory enterprise. There is a line item in the agency's budget for science and technology, which includes costs (primarily salaries) for scientists, and so on, for laboratory scientists and those working in nonlaboratory settings (such as risk assessors), and there is another line item for capital expenditures that includes the laboratories' capital equipment and other capital needs of the agency. But there is not a line item in the agency's budget for just the laboratory enterprise. The funds for the ORD laboratories can be identified in the budget, funding for the program office laboratories can be extracted from the program offices' budgets, and funding for the regional office laboratories can be extracted from the regional offices' budgets. But it appears that EPA does not routinely add all the numbers together to produce a laboratory enterprise budget.[7]

That may be a function of the fact, noted above, that EPA has traditionally viewed the laboratory enterprise as many components, not as a single cohesive enterprise. In that light, it may not have been thought important for EPA to know how much was actually budgeted for the laboratory enterprise or for each of the individual laboratories, wherever they are on an organization chart.[8] If there were a reorientation that would bring EPA to view the laboratory enterprise as a coherent system of various components operating together at some level, such information would be valuable in enabling EPA to manage that entity.

Some of this information may become available from the EPA's current facility-level analysis (see Chapter 1). EPA itself can undoubtedly generate other data internally. Having such data would enable EPA not only to ensure that its available resources are being allocated to projects of the highest priority for the agency but to make comparisons among similarly situated laboratories and to have a benchmark for contract laboratories or university researchers when it chooses to outsource some of it work. It would also enable EPA to determine more easily the marginal cost of new laboratory capacity, equipment, or capabilities. And it would enable EPA to determine more easily whether its budget provides for long-term laboratory needs, especially whether there is room in the budget for emerging issues. It is often said that what gets measured gets managed. Equally important, it would enable outsiders to understand and evaluate EPA's choices better. Indeed, as resources become even more constrained and the scientific issues

[6]Personnel in the program office and regional office laboratories have the best insight into what is happening on the ground (for example, the compliance issue in the regions) or into the tricky questions in drafting regulations or standards (for example, measurement issues in the program office laboratories). Such insight would be valuable for planning purposes as well as for operational issues.

[7]In presentations to the committee, EPA representatives continually stressed that the laboratories do not receive budgets but rather that ORD, the programs, and the regions receive budgets and these entities, depending on their specific priorities, provide funding to their associated laboratories to support projects that ORD, the programs, and the regions have attached priorities to.

[8]This may have been accepted practice because the Office of Management and Budget does not usually ask agencies to provide budget information below the program or project level.

related to the environment become more complex and demanding, it may well be critical for EPA to have these types of data so that it can defend its need for resources or increased resources for the laboratories to carry out their functions.

EPA's staff and leaders may be reluctant to break out laboratory costs. For example, it might make some activities vulnerable to being eliminated by the Office of Management and Budget or Congress in its attempt to delete items that are expensive or controversial. However, it is just as likely that if EPA has reliable data to support its research, it will be able to withstand many such pressures. Accordingly, **EPA should conduct an annual internal accounting of the cost of the entire laboratory enterprise as a basis for assessing efficiency and assisting in planning.** ***(Recommendation 4-4)***

Implementation and Allocation

The Committee did not have the time or the resources to begin to answer several questions regarding implementation, including this one: Are there sufficient people, facilities, equipment and instrumentation, and funds to carry out the annual work plan? However, the committee identified two ways in which we believe greater use of traditional management processes could be used to strengthen EPA's laboratory enterprise. The first is related to developing or capitalizing on assets (especially people) that can be used to respond to or resolve common problems throughout the laboratory enterprise, and the second is related to enhancing the likelihood that funding for work in the laboratory enterprise is directed to the agency's highest priorities.

Personnel Deployment

Once a research project has begun, there may be discussion or collaboration among scientists, technicians, and engineers throughout the laboratory enterprise—indeed, throughout the agency—and with colleagues in other parts of the federal government; in state, local, or tribal agencies; in the private sector; or even in international agencies.[9] As with planning, however, such cross-fertilization appears to be ad hoc rather than the result of any systematic process.

The committee was nonetheless encouraged by briefings on two undertakings that capture the essence (in different ways) of an approach that would use the expertise, talents, and general capabilities of all its laboratories personnel more efficiently. The first is the National Center for Computational Toxicology (NCCT). The NCCT is a relatively small ORD center, founded in 2005, that has 15 federal full-time-equivalent personnel, 30 research fellows and contractors, and a budget of about $7 million in FY2013. The mission of the center is "to integrate modern computing and information technology with molecular biology to improve Agency prioritization of data requirements and risk assessment of chemicals" (Kavlock 2009). Although it is an ORD center, its expertise can be deployed to assist all the EPA laboratories—ORD, regional office, and program office laboratories—when confronted with issues that would benefit from these specialized skills and thereby eliminate the need to replicate this type of service in different laboratories in the laboratory enterprise.[10]

A second undertaking is that of the Emergency Response Laboratory Network (ERLN) mentioned in Chapter 1 and the National Homeland Security Research Center. The center's mission is to "conduct re-

[9]Examples include the development and validation of methods to assess the exposure of honey bees to agricultural pesticides. In this instance, Office of Chemical Safety and Pollution Prevention laboratories worked with the Office of Pesticide Programs Environmental Fate and Effects Division.

[10]A program office laboratory that has a similar cross-EPA role is the National Analytical Radiation Environmental Laboratory (NAREL), whose missions are sample analysis, technical assistance, and guidance related to radiation. "NAREL is EPA's only radiation laboratory and provides analytical support and technical Assistance to ORIA [Office of Radiation and Indoor Air], the EPA regions, other EPA offices, and other federal agencies and states" (Griggs 2013). EPA also defines NAREL as the National Air and Radiation Environmental Laboratory.

search and develop scientific products that improve the capability of the Agency to carry out its homeland security responsibilities";[11] it is primarily in and staffed by ORD's Cincinnati facilities and is a major contributor to the ERLN. Unlike those in NCCT, ERLN participants are not colocated but rather work from 148 federal, state, and commercial locations and form a virtual analytic network, maintaining their day jobs but linked for rapid responses for issues that they are prepared to deal with.[12]

Both those models (and others are available) pool or draw from the skills, expertise, and experience of the scientists, technicians, and engineers that work in the various components of the laboratory enterprise. The committee commends EPA for developing these variations of entities within the laboratory enterprise and encourages it not only to continue its support of these and similar entities but to look for other opportunities in which different laboratories might encounter the same or similar problems, issues, or obstacles and a centralized resource—real or virtual—can assist in their resolution. In short, **EPA should continue to look for innovative ways to address emerging problems and opportunities that create synergies among agency personnel who might encounter similar problems or opportunities within different EPA laboratories within ORD, program offices, and regional offices.** ***(Recommendation 4-5)***

Funding Allocations

The previous discussion was focused on pooling resources, but another process whereby the laboratory enterprise can be strengthened involves the allocation of common resources (the funding authorized by Congress) to the various laboratory activities in a way that is aimed at the strategic goals of the agency. During our information-gathering sessions, EPA representatives continually stressed that the laboratories are not allocated funds from a single source. Instead, the program offices, the regional offices, and ORD receive budgets, and these entities, depending on their own priorities, provide funding to their associated laboratories to support projects to which the programs, regions, or ORD have assigned high priority.[13] We are not aware of any important shortfalls or lapses in laboratory-related activities with this approach, but it is troublesome that there is no process whereby the entire portfolio of laboratory projects can be arrayed to enable an evaluation of whether available funds are being allocated to activities so as to align best with the agency's mission. Moreover, if resources are constrained further, as they might well be, there is no systematic way to ensure that the funds will be directed to the projects of highest priority to the agency.

Earlier in this chapter, when we discussed the potential benefits of having more robust budget information for the planning process, we focused on the costs of individual laboratories. This section goes one step further to recommend that **EPA compile adequate data regarding the costs of individual activities in the various laboratories so that it can manage the laboratory enterprise appropriately.** ***(Recommendation 4-6)***

It is not clear from the information that we received from EPA how the various laboratories determine how much a specific laboratory project will cost when they provide an estimate for budgeting and planning purposes or whether any specific cost accounting is maintained by a given laboratory in implementing a project—be it a short turn-around project conducted by a regional office laboratory or a multi-year scientific research project undertaken by an ORD laboratory—so that it can monitor costs during the life cycle of an activity and refine budgeting procedures. The overall aim should be for EPA to have the ability to produce fairly accurate estimates of costs for implementing various types of laboratory activities

[11] The center was charged by presidential directive for EPA to be the lead agency in coordinating protection of the nation's water infrastructure and efforts to decontaminate outdoor and indoor environments.

[12] The center does have a core staff of 48 people but can scale up to meet needs.

[13] In ORD, each national program director receives a research budget through a process of setting priorities for specific research projects that have been identified as part of the annual strategic planning process. The program directors then go to the ORD laboratories and ask what part of the high-priority items can be done with the available funds.

before undertaking a project and be able to provide final costs at the completion of the project.[14] (Principle 4-3) EPA can use such data to compare the costs of similar projects in different laboratories,[15] to benchmark for any outsourcing that may be contemplated for similar projects,[16] or to answer fundamental questions about benefit–cost ratios for different projects undertaken in various laboratories.[17]

Assessment

As discussed in Chapter 2, the test of effectiveness focuses on the utility of the laboratory enterprise outputs and outcomes for the agency's science consumers. The hallmarks are relevance, quality, cost effectiveness, and maximum usefulness in meeting the priorities and anticipated needs of the program offices and regional offices. Communication throughout the agency, as discussed below, provides the foundation for the planning and implementation phases of the work of the laboratory enterprise. The assessment phase provides verification of the process and informs planning and budgeting for laboratory activities.

Most successful organizations use both internal and external mechanisms for assessment. (Principle 4-4) The ORD planning process described in Chapter 2 provides the internal feedback for the relevance and utility of the outputs of the ORD laboratories. Also the proximity (in both location and relationships) that the program office and regional office laboratories enjoy with their offices should generally ensure that their outputs are relevant and useful for the decision-making undertaken by their offices, and these laboratories do undertake some systematic internal assessment. Expansion of the planning and implementation processes recommended above would probably provide a step in the right direction toward such an internal assessment process. In addition, it is important for managers to focus specifically on such questions as the following:

- Are the results of sufficient quality to be useful?
- Does the research address the problem, and is it ready for implementation?
- Does the work continue to reflect current program or compliance priorities?

EPA's program office laboratories and regional office laboratories should undergo regular internal reviews of their efficiency and effectiveness. *(Recommendation 4-7)*

ORD not only has an internal assessment process but uses external review for assessment. In particular, the Board of Scientific Counselors (BOSC), a committee convened under the Federal Advisory Committee Act (FACA), is charged with providing technical and management advice regarding ORD's research program and program plan development.[18] The BOSC executive board meets three times a year with ORD and conducts a continuous peer review of ORD's centers, laboratories, and research programs aligned with ORD's 5-year strategic plan. The review includes midcycle program progress assessments. The BOSC focus is to ascertain that the right science is being done and that it is being done well in sup-

[14]Although this may seem a daunting task, it is akin to the information that proposers routinely submit as part of the grant-submission process and then at the conclusion of the work done under the grant. In the era of big data, this information is "knowable". For instance, the statistical agencies have long been able to calculate the cost per case for each survey respondent.

[15]Surely, several regional office laboratories undertake substantially similar measurement or testing projects for their regional offices; although the work may be the same, the costs may not be (for a variety of reasons).

[16]EPA reports on the success of the Ann Arbor vehicle-testing laboratory, but the committee is not aware of any data on the budget of the laboratory, how much a specific testing project costs, or how the cost compare with those of external laboratories.

[17]For instance, in retrospect the actual costs of the very successful polychlorinated biphenyls project in Region 1 might be trivial compared with the benefits of the project.

[18]BOSC communicates to the EPA administrator through the assistant administrator for ORD. When a federal agency establishes an advisory group, the agency may be required to comply with FACA if the group has one or more members who are not federal government employees. See EPA 2010.

port of the strategic plan and EPA's mission. BOSC has reciprocal liaison with EPA's Science Advisory Board (SAB), another FACA committee, which has a broader technical mandate to advise the agency on program development, research planning, and research-program balance, including implementation of the Strategic Research Action Plan. The SAB also reviews specific guidance, white papers, and reports that result from ORD and program office activities. However, such requests are ad hoc, and there is no similar process for external review of the outputs of the program office and regional office laboratories. Given the benefits of the external reviews, but recognizing that they are not cost-free, either in money or in person-hours of relevant EPA staff, the committee recommends that **EPA expand the use of external reviews to cover all components of its laboratory enterprise.** ***(Recommendation 4-8)***

Communication

This chapter has included a number of recommendations for improving the management processes in the laboratory enterprise. Our objective is to help EPA to think about the enterprise not so much as a group of individual components but as a system of various scientific and technical efforts within EPA all of whose various laboratories support and advance the agency's mission. To that end, the most important process —and the glue that will hold the enterprise together—is communication.

As emphasized in summary principle 7, communication in an organization goes to the heart of what the organization is about. Effective communication helps to keep employees working well together and reinforces the best tendencies of an organization. Tight-knit organizations thrive on and depend on close communication. It is even more important in a diversified and distributed enterprise to share information about priorities, practices, and problems. Without adequate communication, misunderstandings can develop, employees can begin to work at cross-purposes, and unnecessary rivalries can develop.

In EPA, with its strong science perspective and multifaceted laboratory enterprise, effective communication is central. It is especially true because EPA maintains a small but diverse laboratory enterprise with a small fraction of the funding available to the larger federal science agencies. It is especially important if EPA is to navigate the process of looking 10 years out in its research agenda.

Like all federal agencies, EPA maintains a matrix management system in which most employees have more than one supervisor or boss. Typically, science employees may have an EPA headquarters boss, a programmatic or regional boss, and bosses who represent particular science disciplines. There is nothing wrong with that situation, and it is unavoidable in a complex, technical federal organization like EPA. But effective communication within and between units is essential to making it work. That means that the program offices and their laboratories need to have close communication with all elements of the laboratory enterprise so that each of the various EPA laboratories understands intimately the needs of the program offices. The program office laboratories are not designed or staffed to solve all the problems that their programs or regions present. The programs therefore reach out to the rest of the EPA laboratory enterprise. It is important for the communication to be two-way so that program offices can stay up to date on what the various laboratories are doing and its relevance to program needs and similarly for the regional offices and their laboratories.

All that requires not only frequent communication but the maintenance of a variety of lines of communication, some of which exist in and some of which will be new to EPA. We recognize that there has been substantial progress in establishing and maintaining channels of communication throughout the agency and between ORD and the program offices and regional offices. For example, each regional office serves, on a rotating basis (see Table 4-1), as the lead regional office assigned with the responsibility for identifying and synthesizing the concerns of the 10 regions into an overall view to inform decision making in specific EPA offices outside of the regions. As another example, an ORD representative attends annual meetings of the regional laboratory directors. Also, the ORD laboratories maintain connections to the program offices through representatives assigned to those offices to ensure that the needs of the program offices are being met; this is a relatively new effort but will be useful for EPA.

TABLE 4-1 EPA Lead Region Assignments[a]

Area of Responsibility	Lead Region FY 2013–2014	Lead Region FY 2015–2016
Office of the Administrator	1	7
Office of Environmental Information	1	5
Office of Administrator and Resources Management Office of the Chief Financial Officer	2	9
Office of Chemical Safety and Pollution Prevention	3	1
Office of Air and Radiation	4	8
Office of Homeland Security	5	-[b]
Office of International and Tribal Affairs	6	-[c]
Office of Solid Waste and Emergency	6	2
Office of Enforcement and Compliance Assurance Office of General Counsel	7	6
Office of Water	8	4
Office of Solid Waste and Emergency Response	9	10
Office of Research and Development & OA-Regional Science & Technology	10	3

[a]A map of the EPA regions is shown in Figure 1-1 of Chapter 1.
[b]Combined with the Office of Solid Waste and Emergency Response
[c]Combined with the Office of the Administrator
Source: Adapted from EPA 2014k.

A question that EPA should consider is whether these efforts should be expanded and explicitly encompass the program office and regional office laboratories, which do not appear to be have established systematic lines of communication other than through their offices. We understand that the program office and regional office laboratories might participate in the weekly staff calls with the administrator's office, (Szaro 2013) that the directors of the regional office laboratories meet with one another, and that there are often ad hoc conferences that include people from the program office and regional office laboratories.

EPA provided many examples of communication (indeed, collaboration) between program office and regional office laboratories and other centers of expertise, both in and outside EPA, and this suggests that such outreach is not unusual. To name a few, the National Enforcement Investigations Center has worked with ORD, program offices, and regional offices to develop techniques for its criminal investigations; the National Vehicle and Fuel Emissions Laboratory has coordinated with ORD on health-effects research with the Oak Ridge National Laboratory and Southwest Research Institute on truck and powertrain test methods and with Argonne National Laboratory on vehicle test methods; and the Microbiology Laboratory, under the Office of Pesticide Programs, works regularly with the Food and Drug Administration, the Center for Disease Control and Prevention, the US Department of Agriculture, and state, local, and tribal governments.

Those and other examples are good and useful steps, but the connections are too important to be left to informal arrangements. Difficult issues can arise as the components of the laboratory enterprise seek to coordinate their work. For example, program and regional offices will need to balance the workloads and capabilities of their dedicated laboratories against the workloads and capabilities of the ORD laboratories; the decision-making process will entail having confidence that the laboratories not under their immediate control are aware of their needs and are bringing their best capabilities to bear. That will take close communication and may require new connections and linkages. It requires persistent management effort and attention; if management is not paying attention to sustaining these lines of communication, they will not achieve their objective. Employees know what is important to management and what is not and focus their efforts accordingly.

The challenge for EPA is to develop mechanisms that permit the effort required to sustain appropriate communication to be handled easily and efficiently, become second nature, and enhance the output and performance of all its laboratories. **EPA should determine precisely what lines of communication are needed, which ones already exist, and which ones should be established. It should then clearly articulate the need for these avenues and the mechanisms by which they will be sustained.** ***(Recommendation 4-9)***

PULLING THE ENTERPRISE TOGETHER

The framework analyses provided in Chapter 2 provide criteria for evaluating the several components of EPA's laboratory enterprise. The same criteria can be applied to the laboratory enterprise as a whole and help to guide future investments, planning, and implementing actions for it. We encourage EPA to develop and strengthen management processes using those criteria, which will enable the individual components to perform better and to be synchronized with each other. Our proposal is not to create an integrated entity but rather to enhance communication and coordination among the various components.

As discussed in Chapter 2, the general criteria of efficiency and effectiveness can be made specific in their application to the different components of the laboratory enterprise. Figures 4-1 through 4-3 include illustrative questions to be asked for each major component and for each phase in the planning–implementation–assessment cycle of each. Questions posed in these figures are aimed at helping EPA better align laboratory activities with the mission as called for in summary principle 2. Figure 4-1, for example, lists questions keyed to each phase of the cycle in ORD laboratories. Figures 4-2 and 4-3 offer comparable specifications for the regional office and program office laboratories, respectively.

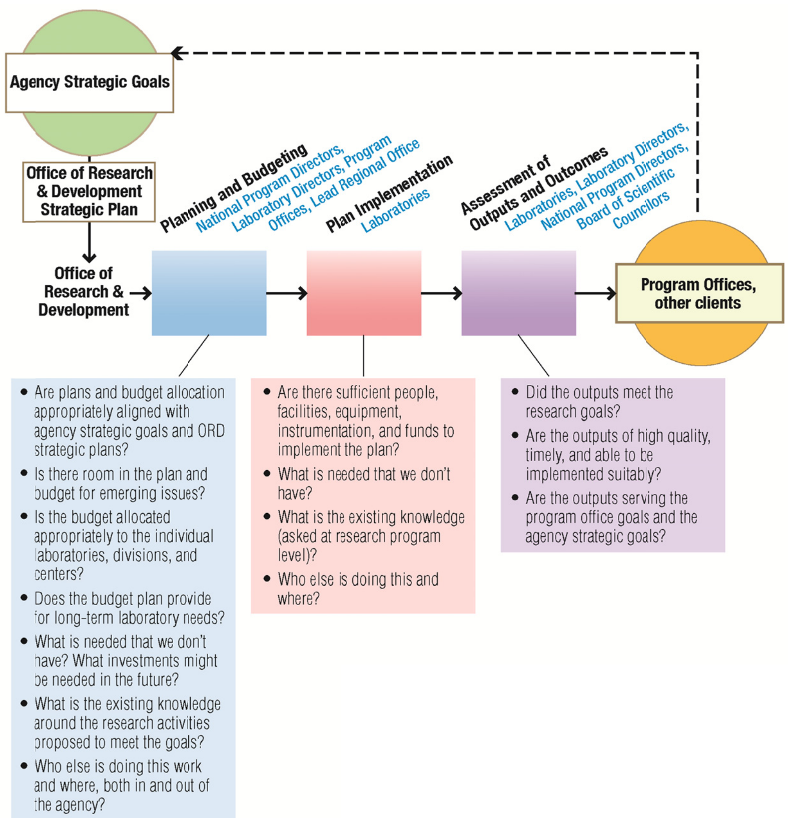

FIGURE 4-1 Aligning agency strategic goals to the ORD portion of the laboratory enterprise.

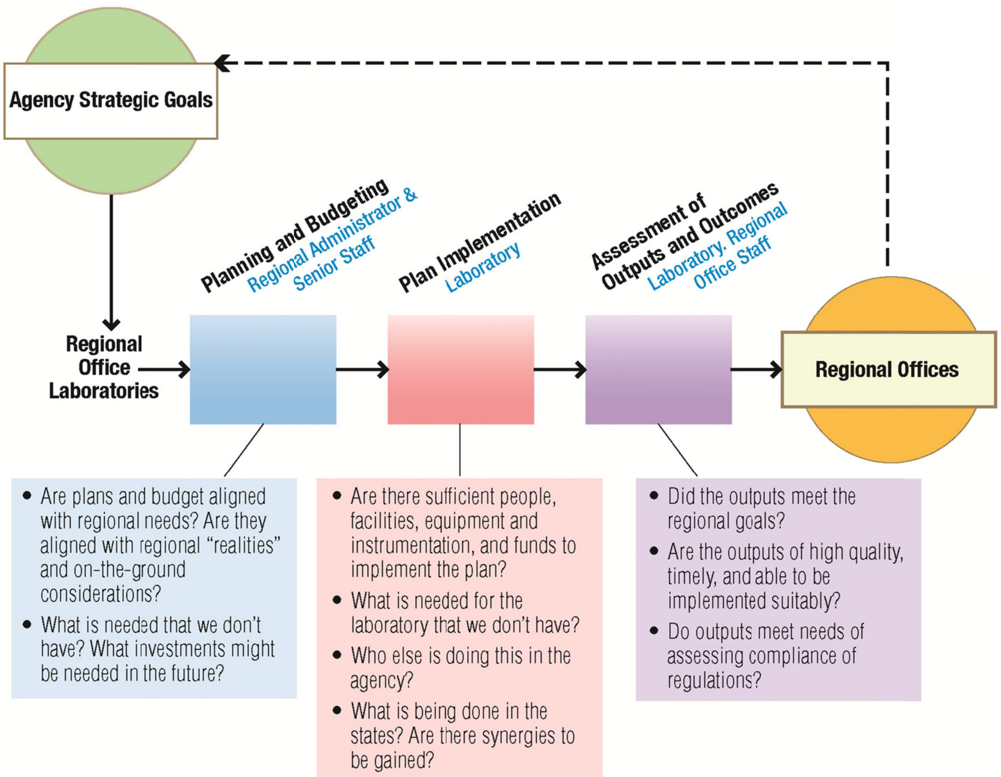

FIGURE 4-2 Aligning agency strategic goals with the regional office laboratories.

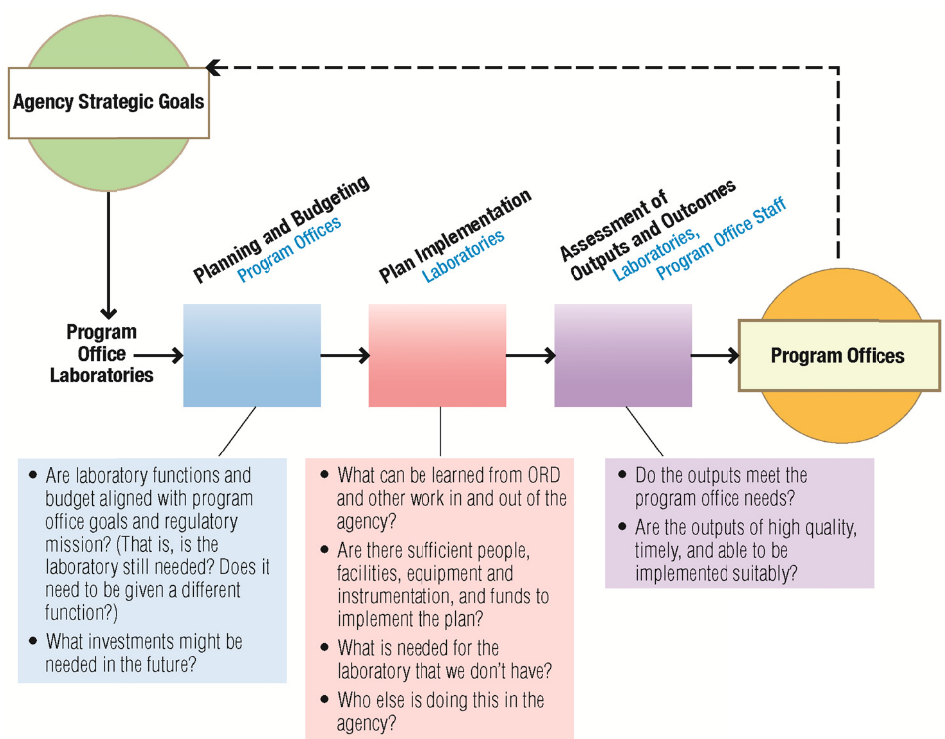

FIGURE 4-3 Aligning agency strategic goals with the program office laboratories.

Using the questions from Figures 4-1, 4-2, and 4-3, management can help to ensure the efficiency and effectiveness of each component of the laboratory enterprise but not necessarily of the enterprise as a whole. Although it is possible that the system functions optimally simply by having each component work well on its own, the agency has experienced substantial gains from greater coordination between ORD and the program offices and regional offices, and this suggests that additional benefits can be achieved by extending the coordination and communication throughout the agency. This experience includes ongoing technology transfers from ORD to the regional office laboratories (up to 20% of ORD's work), the marshaling of agencywide resources to form the virtual ERLN, and the creation of laboratories with cross-EPA functions, such as the NCCT and the National Analytical Radiation Environmental Laboratory. It also includes single-event collaborations such as EPA's response to the Deepwater Horizon oil spill in 2010. This experience is testimony not only to the fruitfulness of past coordination efforts but to the promise of measures to strengthen and systematize coordination in the future.

Figure 4-4 represents the laboratory enterprise as a composite of its three main components, which are represented separately above. The dotted lines connecting the components represent added efficiency and effectiveness to be gained through enhanced communication and coordination.

Cross-cutting questions analogous to those for the individual components can be framed for the laboratory enterprise as a whole. For example, at the level of planning and budgeting for the enterprise, it would be important to ask regularly

- Whether the agency's laboratories have the right personnel, facilities, and equipment to perform their functions and whether those resources are allocated among functions in a way that maximizes the overall contribution to meeting the agency's goals.
- Whether the right balance between meeting short-term needs and building long-term capacity is being maintained across the enterprise as a whole.
- Whether appropriate provision is being made for interdisciplinary or multimedia work that does not fit within the purview of an individual program office.
- Whether there are collaborations or other synergies that would enhance efficiency and effectiveness further. This last question would include potential collaboration not only among EPA laboratories but with other federal agencies, states and tribes, universities, and the private sector.

In implementation, questions that would benefit from an enterprisewide perspective include

- Whether there is sufficient capacity (workforce, facilities, and equipment) at the project or activity level.
- Whether additional needed capacity is available in the laboratory enterprise or from other federal agencies, states, universities, or the private sector.
- Whether redirection may be necessary in response to changed circumstances, including changes in immediate or long-term needs or priorities.

Finally, at the assessment stage, the agency could benefit from enterprisewide answers to such questions as

- Whether outcomes are meeting the needs of all affected program elements, when outcomes have multiple applications.
- Whether outcomes suggest the need for similar work elsewhere in the agency (for example, a regional office laboratory investigation to address a problem that may warrant attention in other regions or nationally).
- Whether systemic factors may be affecting performance throughout the laboratory enterprise.
- Whether practices that have improved the usefulness, timeliness, or cost effectiveness of the work of one component can be used to advantage elsewhere in the system.

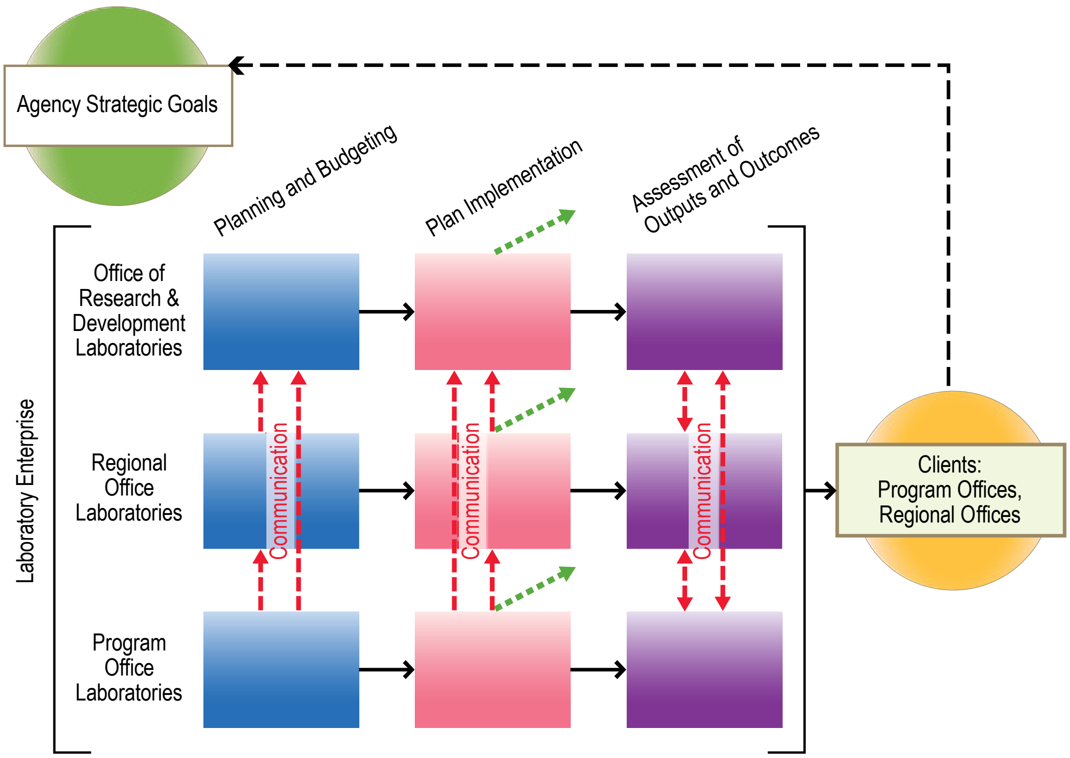

FIGURE 4-4 The overall laboratory enterprise with emphasis on lines and directions of communication that should be institutionalized. In addition to communication, the dashed red lines represent coordination within the enterprise; the dotted green lines under "Implementation" indicate where EPA must reach out to other agencies, academe, and other research organizations to inquire about what is going on concurrently in relation to a given science need.

The Agency is already asking some of those questions and acting on answers to them through processes specific to each component of the laboratory enterprise and informal networks that operate among them, as described earlier in this chapter. The gains from informal collaboration persuade us, however, that the laboratory enterprise would realize even greater benefits from more formal and systematic arrangements for communication and coordination. For that reason, we strongly urge **EPA to use the frameworks presented in Figures 4-1 through 4-4 for the individual components of the laboratory enterprise and for the laboratory enterprise as a whole. *(Recommendation 4-10)***

We are not recommending that the entire enterprise be directed or managed by a single person, nor are we recommending that it be operated as a single entity. On further examination, we believe that the Government Accountability Office (GAO) understanding of the diverse components of the laboratory enterprise and their ability to contribute to the mission of the agency in different ways may have been incomplete and may have led GAO to oversimplify its recommendation. Rather, we envision that the enterprise would seek to preserve the strengths of the individual components but provide for more systematic communication and coordination among them. We discussed enhanced communication above and recommended that it build on the lines of communication that already exist. Similarly, enhanced coordination can be built on existing networks and processes.

There are several possibilities for structuring the coordinating entity. One option would be to use the existing Science and Technology Policy Council (STPC), an agencywide committee that is chaired by the science advisor, who reports to the administrator and deputy administrator. The objective is to have participants with diverse backgrounds and experience provide familiarity and authority with the operations of the various components of the enterprise. An alternative option would be to task the EPA deputy administrator, the science advisor, or the ORD assistant administrator with responsibility for overseeing an assemblage of relevant people from the various components of the laboratory enterprise and to give the program office and regional office laboratory managers dotted-line (secondary or indirect) responsibilities to that person. We have identified several available options, **the committee recommends that the means of implementing the vision for the laboratory enterprise be determined by the EPA administrator with a view to meeting the functional criteria set forth in this report for enhancing the efficiency and effectiveness of the enterprise.** ***(Recommendation 4-11)***

We recognize that the STPC has already been assigned some functions and that it has several subgroups, one of which is designated as a working group for the EPA laboratory enterprise.[19] But, as discussed above, EPA has not thought of its various laboratories as an organized composition of diverse components, and most of the efforts of the working group have been related to one or more of the components. With the reorientation suggested above and given the importance of enhanced communication and coordination, the tasks of the managing entity for the enterprise could well include a needs assessment, an inventory of equipment and facilities, an inventory of skills, and development of training programs. Here, as above, although we have identified some tasks for the managing entity, the committee believes that the design of a suitable communication and coordination function is for the administrator and the administrator's senior team.

We are sensitive to the concern that communication and coordination themselves are not costless and that efforts to overspecify dispersed systems, such as EPA's laboratory enterprise, may impose more burdens than benefits. The test of any move toward greater coordination is whether it improves the efficiency and effectiveness of the whole enterprise when costs of coordination are taken into account. We are persuaded, however, that a properly reoriented EPA laboratory enterprise could be more efficient, make greater contributions to achieving the agency's goals, and have more effective interactions with other agencies and with the larger scientific community, both nationally and internationally.

COLLABORATION WITH ENTITIES BEYOND EPA

The committee's charge states that the committee "will develop principles for the efficient and effective management of EPA's Laboratory Enterprise to meet the agency's mission needs and strategic goals" while "*recognizing the potential contributions of external sources of scientific information from other government agencies, industry, and academia in the U.S. and other nations* [emphasis added]." Summary principle 9 emphasizes this need for linkages to universities, industry, and other government partners. A closely related consideration is the need to avoid duplication of capabilities readily available outside EPA, as called for in summary principle 3. EPA has a broad array of responsibilities and mandates, and its mission requires a wide variety of scientific knowledge, much of which needs to be based on data produced by scientific laboratories through experimentation and analysis of environmental samples. The US national research program related to environmental science is extensive and extends well outside the boundaries of EPA. The federal government supports research in environmental science that is useful for EPA's mission through many programs and agencies, including the National Science Foundation, the Department of the Interior, the Department of Energy, the National Institutes of Health, the Department of Defense, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration. Research is also conducted in universities, in national laboratories, and by various other contractors. And research and collection of environmental data are undertaken by state agencies, private industry, nongovernmental organizations, and consulting firms. Furthermore, as noted in

[19]According to EPA's Web site, "The Science and Technology Policy Council (STPC) serves as a mechanism for addressing EPA's many significant science policy issues that go beyond regional and program boundaries. With a goal of integrating policies that guide Agency decision-makers in their use of scientific and technical information, the STPC works to implement and ensure the success of selected initiatives recommended by external advisory bodies such as the National Research Council and the Science Advisory Board, as well as others such as the Congress, industry and environmental groups, and Agency staff. In this way, the STPC contributes guidance for selected EPA regulatory and enforcement policies and decisions." (EPA 2013b)

the charge to the committee, the United States does not have an exclusive claim to research in environmental science: relevant research is also conducted in other countries.

An effective EPA laboratory enterprise should be fully cognizant of the array of research conducted outside EPA laboratories, should have mechanisms and programs to capitalize on that scientific work, and should have plans and staffs in its own laboratories not only to accomplish work necessary for its mission but to complement efforts of other agencies and to provide a means of collecting, sorting, and analyzing the results of those efforts to serve EPA's mission. (Principle 4-5) There is evidence that EPA does this and that it recognizes the need to incorporate relevant non-EPA research. Several specific examples of collaboration with other agencies and universities were provided to the committee (such as collaborations between EPA laboratories and the California Air Resources Board to develop approaches for improving air quality). However, the preponderance of information and the overall tenor of our discussions with EPA managers suggested that EPA is focused mostly on internal organization and on the procedures for distributing needed work among the EPA laboratories.

The primary mechanism that we are aware of for engaging universities in work related to EPA's mission is the Science to Achieve Results (STAR) program, which we believe is a valuable and effective means of meeting some part of the need to use outside expertise. The STAR program, however, is small relative to the overall US and international effort in environmental science. It is also small relative to the ORD budget. As discussed in Chapter 3, training grants constitute a mechanism for building bridges to the university research community, as does the reinstitution of the postdoctoral program. Both programs can provide the types of expertise needed to conduct research either within the agency laboratory system or in a university laboratory. The committee endorses both programs because they can enhance the awareness of mission-relevant research performed outside EPA. In addition, EPA should reconsider the undergraduate and STAR graduate fellowships in environment-related fields that are no longer offered in 2014*)*. Such programs seem to be important if EPA is to provide a foundation in environmental science and engineering that would allow flexibility for it either to have relevant research performed outside EPA or to acquire staff for its inhouse expertise.

In addition to reaching out to universities, EPA has established a diverse set of industry partnerships.[20] For example, the Automobile Industry/Government Emissions Research (AIGER) Cooperative Research and Development Agreement (CRADA)[21] was set up to identify, encourage, evaluate, and develop instrumentation and techniques for measuring emissions from motor vehicles accurately and efficiently. The technologies developed under that CRADA are intended to be commercialized and be made readily available for emission-testing activities. It is important for EPA to communicate internally throughout the organization about such private-sector interactions and their potential benefits, such as benchmarking EPA laboratories against laboratories doing similar work in the private sector.

EPA clearly needs to have a substantial amount of high-quality inhouse scientific expertise and laboratory capabilities because it typically needs to answer specific questions related to regulation and enforcement and questions related to environmental effects of specific chemicals, activities, and processes. Other entities may produce relevant information in many circumstances, but it is EPA that must have the expertise to recognize the relevance of information, evaluate its quality, and synthesize it for specific purposes. EPA is also faced with situations in which research or analytic work is urgent, so it is imperative that it have access to dedicated staff and facilities that can respond quickly to such needs. Although we can surmise and in some cases identify which of EPA's laboratory facilities and associated scientists are required for the agency's mission, it would behoove the agency to develop criteria for determining which capabilities need to be maintained inhouse and which potential new capabilities that might be required in the future should be developed inhouse as opposed to being acquired through partnerships. Such an ap-

[20]EPA's Office of Acquisition Management provides information on current procurement opportunities (EPA 2014l).

[21]Members of the AIGER CRADA are EPA, the California Air Resources Board, and the US Council for Automotive Research, which includes Chrysler LLC, Ford Motor Company, and General Motors Corporation (EPA 2013c).

proach would be consistent with summary principle 3, which is concerned about avoiding duplication of capabilities that are readily available externally.

Many problems require specific data to be generated to address environmental issues, but data are being generated globally at an enormous rate, and this has created the challenge of maintaining the capability to take advantage of the rapidly expanding knowledge base. It is critical for EPA to have a strong capability for accumulating, managing, and mining extremely large datasets from diverse sources related to its mission. Such a capability is a critical component of efficient use of its laboratory facilities and scientific staff.

Assuming that effective use of the agency's scientific and technical capabilities requires optimal use of non-EPA scientific resources, there should be a process by which identified research priorities are accompanied by assessment of whether further research is needed and then assessment of the best way to obtain that research. Presumably, it might be preferable in many cases to partner or contract with other agencies to obtain the needed research, and it might be best in an equal number of cases to have the research done by EPA scientists in EPA laboratories. Although we have been given evidence that much of that process is used, we did not see an explanation of how it is determined whether and which outside sources of information should be used. **EPA should develop more explicit plans for partnering with other agencies (federal and state), academia, industry, and other organizations to clarify how it uses other federal and nonfederal knowledge resources, how it maintains scientific capabilities that are uniquely and critically needed in the agency, and how it avoids unnecessary duplication of the efforts or capabilities of the other agencies.** ***(Recommendation 4-12)***

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As discussed above, the committee was not tasked with reorganizing or redesigning the EPA laboratory enterprise. However, in suggesting the principles and recommendations that we have developed, we believe that EPA now has the tools needed to design and implement a plan for enhancing the efficiency and effectiveness of its network of laboratories.

5

Addressing Future Challenges

Numerous studies of the US Environmental Protection Agency (EPA) have identified foreseeable future issues that the agency will face in meeting its mission. See Box 5-1 for examples of such emerging issues, which were identified in part by a 2012 National Research Council report (NRC 2012a). In some cases, addressing the emerging issues will present substantial new scientific and technical challenges. This chapter focuses on how the agency can structure its workforce, research and technical infrastructure, and management to account for and address emerging issues. This is relevant to summary principle 2, which indicates essential laboratory capabilities are the ones that are relevant to the current mission and the ones that anticipate future mission needs.

Interactions with state and local governments as part of EPA's regulatory function provide opportunities to hear from and maintain a discussion with those who are confronting emerging issues daily. EPA research priority setting and planning could be enhanced if agency program managers assist agency researchers in accessing this resource. An appropriate extension of this "listening" process with state and local governments is to include universities, industry, and other federal agencies. Broadening the interactions to include the international community presents even more opportunities to identify emerging issues, gain different perspectives, and gauge the importance of issues.

More structured approaches to identifying emerging issues should include formal analyses of future societal scenarios and their ramifications. EPA successfully incorporated some of these analytic techniques in coming to understand how it would use the emerging fields of genomics and proteomics in fulfilling its regulatory mission.

BOX 5-1 Examples of Emerging Environmental Challenges with Potentially Large Effects on Human Health, Species, and Ecosystems[1]

- Human and environmental exposure to toxic chemicals.
- Loss of native biodiversity.
- New stressors from climate change that affect human health, the built infrastructure, social institutions, and natural ecosystems.
- Degradation of surface-water quality and coastal ecosystems as a result of agricultural runoff, aging of sewage-treatment infrastructure, and land-use change.
- Exposure to new chemicals and nanomaterials.
- Growth in the volume and changes in composition of solid waste, such as increases in hormonally active products in household waste streams.
- Development of large and complex datasets by modern and future research initiatives (big data).
- Synthetic biology and biosecurity.
- New biomarker techniques.

[1]The list is based on NRC 2012a and the committee's deliberations.

Advisory groups, such as EPA's Science Advisory Board (SAB) and advisory bodies established to provide independent expert advice to specific types of EPA laboratories , can also contribute to the process of identifying and evaluating emerging issues. Those groups can provide perspective on the value of emerging tools for the agency. They do that through various mechanisms that have different degrees of agency participation including roundtable discussions, workshops, and minisymposia. Box 5-1 lists some issues and developments that the groups (e.g., NRC 2012a) have identified as future drivers of research and other science and engineering activities in EPA. The present committee augmented the list with several other items, such as the large and complex datasets that are the products of modern and future research (referred to as big data) (NRC 2013). High-throughput technologies and ubiquitous sensing arrays, which comprise a source of big data, will challenge researchers and provide important opportunities for understanding biological responses to environmental chemical exposures (NRC 2007). Increased collaboration with other government and nongovernment institutions in meeting the challenge of working with big data will exacerbate operational hurdles but amplify the opportunities. In addition, the committee sees a need to relist biomarkers, which were identified more than 2 decades ago (NRC 1989a, 1989b, 1992a, 1992b, 1995), as an opportunity to apply molecular techniques and as a tool for the future in environmental health. Progress has been slow, but the developments in related fields have brought the use of biomarkers to the fore again. **EPA should consider using a variety of structured approaches for identifying emerging issues and possible solutions, including formal analyses of future societal scenarios and their ramifications and third-party advisory groups.** ***(Recommendation 5-1)***

Some government departments establish robust programs that they use to anticipate developments and possible responses. The Department of Defense's Defense Advanced Research Projects Agency (DARPA) is often cited in this regard and emulated by others, for example, the Department of Energy's Advanced Research Projects Agency – Energy (ARPA-E) program. EPA has made occasional forays in this direction, such as the National Center for Computational Toxicology and the interagency collaboration known as Tox21, that have successfully placed EPA in a position to address emerging issues and use emerging tools. In fact, the agency could marshal a small E-ARPA, an Environmental Advanced Research Projects Alliance, by using the various institutional research tools that it has already developed. Faced with a serious emerging issue or substantial opportunity to take advantage of new knowledge or technologies, the agency could involve universities and the private sector through its ability to develop cooperative agreements, to issue contracts and grants through its Science To Achieve Results (STAR) grants program, and to coordinate the different departments of the government and the different elements of the agency's own scientific expertise. **EPA should consider creating an E-ARPA and also consider how and under what circumstances E-ARPA efforts could be managed to address the agency's future scientific and technical needs.** ***(Recommendation 5-2)*** Although it did not attempt to estimate the funding requirements for this alliance, the committee does not anticipate that E-ARPA would involve a programmatic effort of comparable magnitude to DOD's and DOE's programs.

Through its continuing workforce development, research and technical infrastructure, and management philosophy, EPA can maintain a robust and facile scientific and engineering enterprise that is capable of dealing with emerging issues and unpredicted developments.

WORKFORCE DEVELOPMENT

EPA needs to continue to develop its present workforce and attract new scientists and engineers who have new skills. A number of current practices are appropriate for doing that (see Chapter 3). They include

- The use of postdoctoral fellows for relatively short technical assignments to provide the agency with a flexible mechanism for bringing state-of-the-science expertise to bear and a pool of individuals for hire.
- Temporary assignments from academe or industry through the Intergovernmental Personnel Act.

- Colocation of EPA laboratory employees with university researchers, as in the case of the Office of Research and Development's epidemiology and human exposure research groups at the University of North Carolina, Chapel Hill.
- Hiring of renowned scientists and engineers under Title 42 authority,
- EPA's recently introduced Innovation Grants, an excellent way to develop intra-Agency expertise rapidly.
- Allowing agency scientists and engineers to take temporary positions in university and industry laboratories.

A key tool for ensuring that students are developing properly to join the workforce of the future is the training-grant program for universities. EPA's Greater Research Opportunities (GRO) fellowships for undergraduate environmental study constitute one example. Such programs attract capable people who will provide EPA and the fields of environmental and ecologic health with emerging skills. Although their use has dropped dramatically as funding has become more scarce, focused efforts to restore them are called for if the agency is to be prepared for the future.

RESEARCH AND TECHNICAL INFRASTRUCTURE

Just as the physical infrastructure is an important consideration for EPA's future, so is the research and technical infrastructure, the expertise of the people who use the physical infrastructure. The committee joins a number of EPA SAB and previous National Research Council committees in supporting growth in the number of scientists who have expertise in the social and behavioral sciences. Those backgrounds are essential for understanding already-identified emerging issues and for fashioning responses, mitigating effects, and finding acceptable long-term solutions. Given the multidisciplinary and transdisciplinary nature of current and emerging issues, formalized efforts involving synthesis are also called for. Examples of relevant syntheses are available from such institutions as the National Center for Ecological Analysis and Synthesis, the Powell Center, and the Socio-Environmental Synthesis Center (SESYNC 2012; NCEAS 2013; Powell Center 2013). Science and engineering will continue to be increasingly data-intensive.

New approaches to doing science to address emerging issues are also necessary. Examples include

- "Group science", whereby informal associations of individual researchers and research institutions address problems.[1]
- Engagement of the public more widely through the offering of XPRIZE-like "E-prizes" for specific developments.[2]
- Use of ubiquitous sensors.

New approaches will demand different techniques for the quality assurance and the analysis of data, including data obtained through meta-analysis. Workforce development activities within EPA will be crucial for ensuring that this information-related revolution can be effectively capitalized on.

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[1]Group science, also referred to as citizen science or crowd science, is a research approach that incorporates the efforts, knowledge, observations, and resources of the general public. For example, people use air-monitoring devices that are linked to smartphones to log, map, and share air-quality data collected from locations where they carry out their daily activities.

[2]XPRIZE refers to a monetary award given to the first team to achieve a specific goal during an incentivized competition in one of five areas: energy & environment, exploration, global development, learning, and life sciences. http://www.xprize.org/.

MANAGEMENT

EPA faces so many near-term deadlines and controversial debates every day that it may be difficult for managers to maintain a focus on scientific and technical workforce development or research and technical infrastructure. But without a competent scientific and technical workforce, the quality of the agency's decision-making will suffer. A focused commitment to workforce development and research infrastructure by career managers and political appointees is essential for sound decision-making and for maintaining a workforce that is capable of identifying and dealing with emerging issues. Success is largely a matter of commitment to a sound scientific and technical workforce and research and technical infrastructure. *(Principle 5-1)*

6

Principles and Recommendations

This chapter presents a compilation of the principles and recommendations discussed in the previous chapters of the report. Relevant specific principles and recommendations from the other chapters are provided following the summary principles from Chapter 3. The committee recognizes that some of the recommendations may be difficult to undertake, and that sufficient resources may not be available to undertake them all in the near term. Therefore EPA will need to set priorities and develop a strategy for addressing them as part of its integrated evaluation of agency laboratories.

A VISION OF THE LABORATORY ENTERPRISE

Summary Principle 1: Every science institution is more effective if it has a vision of how its scientists, technicians, and other professionals can best contribute to the organization's mission and goals.

Principle 4-1: An important part of management is knowing what the entity is and what it is intended to do, and this is true of every scientific institution as well.

EPA should approach management of its laboratory enterprise not so much as separate types of laboratories but as a system of the various laboratory efforts in EPA in which science and technical support activities are undertaken to support and advance the agency's mission–in other words, as an organized composition of diverse components. ***(Recommendation 4-1)***

EPA should develop a vision for its laboratory enterprise that maintains the strengths of the individual components but provides synergy through systematic collaboration and communication throughout the agency. ***(Recommendation 4-2)***

ENSURING LABORATORY FUNCTIONS MEET THE HIGHEST-PRIORITY MISSION NEEDS

Summary Principle 2: Essential laboratory capabilities are the ones that are relevant to the current mission and the ones that anticipate future mission needs. Priorities for laboratory capabilities should focus on work that is central to the agency's mission rather than on small peripheral efforts.

Summary Principle 3: Laboratories should avoid internal redundancy or duplication of capabilities that are readily available externally.

EPA should use the frameworks presented in Figures 4-1 through 4-4 for the individual components of the laboratory enterprise and for the laboratory enterprise as a whole. ***(Recommendation 4-10)***

WORKFORCE

Summary Principle 4: Recruiting, developing, and retaining an outstanding, committed scientific and technical workforce is crucial for maintaining outstanding laboratory capabilities.

EPA should continue and strengthen its characterization and evaluation of its laboratory workforce, establishing a defined timeline and being transparent in its processes for internal and external audiences. ***(Recommendation 3-1)***

EPA should initiate or complete the development of a strategy for periodically addressing the composition of the workforce, in the ORD laboratories, the regional office laboratories, and the program office laboratories, particularly after completion of the Voluntary Separation Incentive Payments/Voluntary Early Retirement Authority actions in 2014. The analysis should include an inventory of skills and training and demographic analysis (for example, projected retirements over the next 5 years) for strategic planning for the future. This information is essential for making sensible decisions in hiring, future reassignments, and offers of voluntary retirements. ***(Recommendation 3-2)***

EPA should continue its planned hiring of postdoctoral researchers by ORD and expand it to other types of laboratories as appropriate. ***(Recommendation 3-6)***

EPA should be granted permanent Title 42 authority and the expanded authority to define the number of Title 42 positions on the basis of its programmatic needs and available budget. In addition, EPA should use an independent body to review the Title 42 program every 5 years to ensure that it is being used for its intended purposes. ***(Recommendation 3-7)***

EPA should continue, enhance, and expand its student training grant programs, such as GRO. The STAR fellowship program should be reinstated in EPA to support the research programs specific to EPA's mission and goals. ***(Recommendation 3-5)***

CAPITAL EQUIPMENT

Summary Principle 5: State-of-the-art facilities and equipment are essential if a laboratory enterprise is to be able to meet current and future mission needs.

EPA should link inventory of equipment over $500,000 in all laboratories, without regard to mission, to an agencywide accessible process. Before investment in large capital equipment, laboratory equipment in other parts of EPA, other agencies, and universities that could be available for shared use should be explored. ***(Recommendation 3-9)***

EPA should continue taking steps to improve the transparency and agencywide awareness of all its laboratory science capabilities. ***(Recommendation 3-10)***

MANAGEMENT

Summary Principle 6: Effective management with appropriate flexibility enables an efficient and effective laboratory enterprise.

The means of implementing the vision for the laboratory enterprise should be determined by the EPA administrator with a view to meeting the functional criteria set forth in this report for enhancing the efficiency and effectiveness of the enterprise. ***(Recommendation 4-11)***

EPA should continue to look for innovative ways to address emerging problems and opportunities that create synergies among agency personnel who might encounter similar problems or opportunities within different EPA laboratories within ORD, program offices, and regional offices. ***(Recommendation 4-5)***

Principle 4-2: Systematic involvement of all the agency's laboratories in the planning process is far preferable to ad hoc connections and would probably yield a stronger and more efficient laboratory enterprise.

EPA should ensure that its laboratory planning process includes cross–regional office and cross–program office laboratory input and that it is more transparent within the agency and to outsiders. ***(Recommendation 4-3)***

Principle 4-3: The overall aim should be for EPA to have the ability to produce fairly accurate estimates of costs for implementing various types of laboratory activities before undertaking a project and be able to provide final costs at the completion of the project.

EPA should conduct an annual internal accounting of the cost of the entire laboratory enterprise as a basis for assessing efficiency and assisting in planning. ***(Recommendation 4-4)***

EPA should compile adequate data regarding the costs of individual activities in the various laboratories so that it can manage the laboratory enterprise appropriately. ***(Recommendation 4-6)***

COMMUNICATION AND PARTNERSHIPS

Summary Principle 7: Communication and coordination among the laboratories within an organization are essential for efficiency and effectiveness.

EPA should continue to cultivate an interdisciplinary scientific workforce at all levels of expertise throughout the laboratory enterprise that can engage in high-quality, collaborative, science activities aimed at transdisciplinary challenges. ***(Recommendation 3-3)***

EPA is encouraged to continue taking steps to improve the transparency and cross-agency awareness of capabilities through enhanced communication regarding scientific and engineering staff expertise and laboratory equipment. ***(Recommendation 3-8)***

EPA should determine precisely what lines of communication are needed, which ones already exist, and which ones should be established. It should then clearly articulate the need for these avenues and the mechanisms by which they will be sustained. ***(Recommendation 4-9)***

ENSURING QUALITY

Summary Principle 8: Outstanding research and other science-related activities are the foundation for meeting current and future mission needs and for sustaining leadership in environmental science and applied research.

Principle 5-1: Success is largely a matter of commitment to a sound scientific and technical workforce and research and technical infrastructure.

Principle 4-4: Most successful organizations use both internal and external mechanisms for assessment.

EPA's program office laboratories and regional office laboratories should undergo regular internal reviews of their efficiency and effectiveness. ***(Recommendation 4-7)***

EPA should expand the use of external reviews to cover all components of its laboratory enterprise. ***(Recommendation 4-8)***

SYNERGIES WITH OTHER ORGANIZATIONS

Summary Principle 9: A strong linkage to universities, industry, research institutions, and other federal and state government organizations enhances the laboratory enterprise and prepares it for the future.

Principle 4-5: An effective EPA laboratory enterprise should be fully cognizant of the array of research conducted outside EPA laboratories, should have mechanisms and programs to capitalize on that scientific work, and should have plans and staffs in its own laboratories not only to accomplish work necessary for its mission but to complement efforts of other agencies and to provide a means of collecting, sorting, and analyzing the results of those efforts to serve EPA's mission.

EPA should develop more explicit plans for partnering with other agencies (federal and state), academia, industry, and other organizations to clarify how it uses other federal and nonfederal knowledge resources, how it maintains scientific capabilities that are uniquely and critically needed in the agency, and how it avoids unnecessary duplication of the efforts or capabilities of the other agencies. ***(Recommendation 4-12)***

EPA should develop relationships with community colleges and universities to enable students to work in EPA laboratories as interns or student employees in an effort to develop future technicians and scientists who will conduct research and other laboratory functions related to EPA needs. ***(Recommendation 3-4)***

EPA should consider using a variety of structured approaches for identifying emerging issues and possible solutions, including formal analyses of future societal scenarios and their ramifications and third-party advisory groups. ***(Recommendation 5-1)***

EPA should consider creating an Environmental Advanced Research Projects Alliance (E-ARPA) and also consider how and under what circumstances E-ARPA efforts could be managed to address the agency's future scientific and technical needs. ***(Recommendation 5-2)***

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Appendix A

Statement of Task

An NRC committee will assess EPA's highest priority needs for mission-relevant laboratory science and technical support, now and during the next ten years. Recognizing the need to operate within budget constraints and growing demands, and recognizing the potential contributions of external sources of scientific information from other government agencies, industry, and academia in the U.S. and other nations, the committee will develop principles for the efficient and effective management of EPA's laboratory enterprise to meet the agency's mission needs and strategic goals. Drawing upon these principles, the committee will develop guidance for enhancing efficiency and effectiveness, now and during the next ten years, which:

- Improves EPA's ability to plan, prioritize, coordinate, and deliver scientific research, technical support, and analytical services from EPA's laboratory enterprise for achieving the highest-priority scientific needs and strategic goals, and for achieving the strategic objectives in the GPRA Modernization Act of 2010 for laboratory and research organizations;
- Uses an analytical framework(s) to ensure that laboratory facilities, functions, scientific solutions, and capabilities are aligned with the highest-priority scientific needs for the agency's strategic goals; and
- Sustains the leadership capability of the laboratory enterprise for environmental science and research.

The committee's work is part of a multi-phase effort by EPA and collaborating organizations to make the agency's laboratory enterprise more effective and efficient while reducing costs. The committee will not assess the organization, or the facility-level and portfolio-level master-plans, or the consolidation initiatives for EPA's laboratory enterprise, because that analysis will be undertaken through a separate effort. EPA will consider the findings and recommendations provided by the committee, as well as the input from other efforts, in developing an implementation plan for the laboratory enterprise. At EPA's discretion, another ad hoc NRC committee may be asked subsequently and funded separately to assess the draft plan.

Appendix B

Biographic Information of the Committee on Strengthening the US Environmental Protection Agency Laboratory Enterprise

Maxine L. Savitz (NAE) *(Chair)* is a retired general manager of technology partnerships at Honeywell, Inc., and has more than 35 years of experience in managing research, development, and implementation programs for the public and private sectors, including the aerospace, transportation, and industrial sectors. From 1979 to 1983, she was deputy assistant secretary for conservation in the US Department of Energy. She is vice president of the National Academy of Engineering and a member of the Governing Board of the National Research Council. Since 2009, she has been a member of the President's Council of Advisors on Science and Technology and is its vice chair. She serves on advisory bodies for the Sandia National Laboratory and Pacific Northwest National Laboratory and is a member of the Board of Directors of the American Council for an Energy-Efficient Economy. Dr. Savitz served on the National Academies Committee on America's Energy Future and was vice chair of the Panel on Energy Efficiency. She is a fellow of the California Council on Science and Technology. Her past board memberships include the National Science Board, the Secretary of Energy Advisory Board, the Defense Science Board, the Electric Power Research Institute, Draper Laboratories, and the Energy Foundation. Dr. Savitz has a PhD in chemistry from the Massachusetts Institute of Technology. She was elected to the National Academy of Engineering in 1992.

Jonathan Z. Cannon *(Vice-Chair)* is the Blaine T. Phillips Distinguished Professor of Environmental Law and director of the Environmental and Land Use Law Program of the University of Virginia (UVA) School of Law. He served on President-Elect Obama's Environmental Protection Agency (EPA) transition team. Before joining the faculty of UVA, Mr. Cannon worked in EPA as general counsel, assistant administrator for administration and resources management, and chief financial officer. His scholarly interests include the design and implementation of environmental programs, the Supreme Court's environmental jurisprudence, and protection of watersheds and landscapes. Mr. Cannon holds a JD from the University of Pennsylvania Law School.

Patricia A. Berge is the deputy associate director for operations in the Physical and Life Sciences Directorate of Lawrence Livermore National Laboratory (LLNL). For the previous 6 years, she led the Atmospheric, Earth, and Energy Division of LLNL where she managed about 150 scientists who were conducting basic and applied research in energy, environment, and national security. Division scientists support LLNL centers and programs, including the Center for Accelerator Mass Spectrometry (CAMS), the Program for Climate Model Diagnosis and Intercomparison (PCMDI), and the National Atmospheric Release Advisory Center (NARAC). Her own research has been in measurement and modeling of elastic and fluid transport properties of porous and cracked rocks. She holds a PhD in geology and geophysics from the University of Hawaii.

Lynda T. Carlson is the recently retired director of the National Center for Science and Engineering Statistics of the National Science Foundation. Previously, she was director of the Statistics and Methods Group Energy Information Administration of the US Department of Energy. Dr. Carlson has substantial professional experience in survey design, development, and operation; in innovative techniques for surveying unique populations; and in the organization and management of statistical groups and projects. She received the Presidential Meritorious Rank Award and the Roger Herriot Award of the American Statistical Association for Innovation in Federal Statistics. Dr. Carlson is a fellow of the American Association for the Advancement of Science and an elected fellow of the American Statistical Association. She was vice-chair of the Organisation for Economic Co-operation and Development Working Group on National Experts on Science and Technology Indicators. She holds a PhD in political science from the University of Illinois.

Philip E. Coyle is a private consultant and senior science adviser to the Center for Arms Control and Non-Proliferation. In 2010 and 2011, Mr. Coyle served as the associate director for national security and international affairs in the White House Office of Science and Technology Policy (OSTP). In that position, he had primary responsibility for supporting President Obama and the director of OSTP in developing and executing a wide variety of science and technology initiatives, including those in universities and laboratories that made up the R&D capabilities of the Department of Defense (DOD), the Department of Energy (DOE), and other federal agencies. In 2005 and 2006, Mr. Coyle served on the nine-member Defense Base Realignment and Closure Commission (BRAC). During the 1995 BRAC, he was cochairman of the DOD Joint Cross-Service Group for Test and Evaluation. From September 1994 through January 2001, Mr. Coyle was assistant secretary of defense and director of operational test and evaluation in DOD. During the Carter administration, he was principal deputy assistant secretary for defense programs in DOE and had oversight responsibility for the nuclear-weapons research, development, production, and testing programs of the department and DOE programs in arms control, nonproliferation, and nuclear safeguards and security. From 1959 to 1979 and again from 1981 to 1993, Mr. Coyle worked at the Lawrence Livermore National Laboratory (LLNL). His work included serving as deputy associate director of the LLNL laser program. In recognition of his years of service to LLNL and to the University of California, the university named Mr. Coyle laboratory associate director emeritus. The International Test and Evaluation Association awarded him its Allan R. Matthews Award, its highest award, for his contributions to the management and technology of testing and evaluation. He was awarded the Defense Distinguished Service Medal by DOD Secretary Perry and the Bronze Palm of the Defense Distinguished Service Medal by DOD Secretary Cohen. Mr. Coyle received an MS in mechanical engineering from Dartmouth College.

Frank W. Davis is a professor in the Donald Bren School of Environmental Science & Management and director of the National Center for Ecological Analysis and Synthesis of the University of California, Santa Barbara. His research interests are in landscape ecology and conservation planning. Dr. Davis's research focuses on the landscape ecology of California plant communities, design of protected-area networks, biodiversity implications of renewable-energy development, and biologic effects of regional climate change in the western United States. He is a fellow of the American Association for the Advancement of Science, a fellow in the Aldo Leopold Leadership Program, and a trustee of the Nature Conservancy of California. Dr. Davis has served on a number of National Research Council committees, starting with the Committee on the Formation of the National Biological Survey in 1993. He served on the Committee on the Restoration of the Greater Everglades Ecosystem and as chair of the Committee on Independent Scientific Review of Everglades Restoration Progress. Most recently, he served on the Committee on Science for EPA's Future and on the Board on Environmental Studies and Toxicology. Dr. Davis earned a PhD in geography and environmental engineering from Johns Hopkins University.

Donald J. DePaolo (NAS) is a professor of geochemistry in the Department of Earth and Planetary Science of the University of California, Berkeley and associate laboratory director for energy and environmental sciences at the Lawrence Berkeley National Laboratory. He directs the Center for Isotope Geochemistry and the Center for Nanoscale Control of Geologic CO_2. He was previously on the faculty of the University of California, Los Angeles. His research focuses on the use of naturally occurring isotopes to explore a variety of Earth-science questions related to mantle dynamics and magma-chamber processes and on tracking fluids moving through groundwater systems to trace contaminates. He holds numerous fellowships, including that of the American Association for the Advancement of Science, and a John Simon Guggenheim Fellowship. He is the recipient of the Harold Urey Medal from the European Association of Geochemistry and the MacElwane Award from the American Geophysical Union. Dr. DePaolo was elected to the National Academy of Sciences in 1993. He holds a PhD in geology from the California Institute of Technology.

Paul Gilman is senior vice president and chief sustainability officer of Covanta Energy Corporation. Previously, he served as director of the Oak Ridge Center for Advanced Studies and as assistant administrator of the Office of Research and Development in the US Environmental Protection Agency (EPA). He also worked in the Office of Management and Budget, where he had oversight responsibilities for the US Department of Energy (DOE), EPA, and all other science agencies. In DOE, he advised the secretary of energy on scientific and technical matters. From 1993 to 1998, Dr. Gilman was the executive director of the National Research Council Commission on Life Sciences and the Board on Agriculture and Natural Resources. He has served on numerous National Research Council committees. Dr. Gilman received a PhD in ecology and evolutionary biology from Johns Hopkins University.

Carol J. Henry is a professorial lecturer in the Department of Environmental and Occupational Health of the George Washington University Milken Institute School of Public Health and an adviser and consultant to public and private organizations. She focuses on issues in toxicology, public and environmental health, risk assessment, risk management, research-management strategies, green chemistry and engineering technology, and sustainable practices. She is consultant and secretary for the Society of Automotive Engineers (SAE) Green Technology Steering Committee and Environmental Health Advisor to Cummins, Inc. Dr. Henry was previously vice president of industry performance programs in the American Chemistry Council, director of the Health and Environmental Sciences Department of the American Petroleum Institute, associate deputy assistant secretary for science and risk policy in the US Department of Energy, and director of the Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency. She is a diplomate of the American Board of Toxicology, certified in general toxicology. Dr. Henry is a member of the NSF International Council of Public Health Consultants, the National Research Council Committee on the Design and Evaluation of Safer Chemical Substitutes, the *Environmental Health Perspectives* Editorial Board, and the American Chemical Society's Committee on Environmental Improvement. Dr. Henry received a PhD in microbiology from the University of Pittsburgh.

Philip K. Hopke is the director of the Institute for a Sustainable Environment and the Bayard D. Clarkson Distinguished Professor in the Department of Chemical and Biomolecular Engineering of Clarkson University. He is also the director of the university's Center for Air Resources Engineering and Sciences. His research interests are primarily related to particles in the air, including particle formation, sampling and analysis, composition, and origin. His current projects are related to solid-biomass combustion, receptor modeling, ambient monitoring, and nucleation. Dr. Hopke has been elected to membership in the International Statistics Institute and is a fellow of the American Association for the Advancement of Science and of the American Association for Aerosol Research; he has been vice president, president, and a member of the Board of Directors of the latter. He is a member of the National Research Council Board on Environmental Studies and Toxicology, the American Institute of Chemical Engineers, the International Society of Exposure Science, and the International Society of Indoor Air Quality and Climate and has been a member of the US Environmental Protection Agency Clean Air Scientific Advisory Committee. Dr. Hopke has served on a number of National Research Council committees, including the Committee on Energy Futures and Air Pollution in Urban China and the United States, the Committee on Research Priorities for Airborne Particulate Matter, and the Committee on Air Quality Management in the United States. He received a PhD in chemistry from Princeton University.

Sally Katzen is a visiting professor of the New York University School of Law and a senior adviser to the Podesta Group in Washington, DC. She previously taught in the University of Michigan Law School, George Mason University Law School, George Washington University School of Law, University of Pennsylvania Law School, Smith College, Johns Hopkins University, and the University of Michigan in Washington Program. Ms.Katzen was administrator of the Office of Information and Regulatory Affairs in the Office of Management and Budget (OMB) in 1993–1998, deputy director of the National Economic Council in the White House in 1998–1999, and deputy director for management in OMB in 2000–20001. Before her government service, she was a partner in the Washington, DC, law firm of Wilmer, Cutler & Pickering and specialized in regulatory and legislative matters. After graduation from law school, she clerked for Judge J. Skelly Wright of the US Court of Appeals for the District of Columbia Circuit. Ms. Katzen is a fellow of the National Academy of Public Administration and a senior fellow of the Administrative Conference of the United States. She served as a member of the National Research Council Committee on Sustainability Linkages in the Federal Government and the Committee on Evaluating the Efficiency of Research and Development Programs at the Environmental Protection Agency. She received a JD from the University of Michigan.

Gary S. Sayler is Beaman Distinguished University Professor of Microbiology, and Ecology and Evolutionary Biology and director of the University of Tennessee–Oak Ridge National Laboratory Joint Institute for Biological Sciences. He is also the founding director of the University of Tennessee Center for Environmental Biotechnology. Dr. Sayler's research interests are in multidisciplinary laboratory and field environmental research; biodegradation of such organic pollutants as polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and trichloroethylene; and the ecologic and toxicologic effects of environmental contaminants on the structure and function of microbial communities. He holds 16 patents, including ones for the extraction and analysis of nucleic acids from soils, environmental gene-probe analysis, and bioluminescence biosensor technology. Dr. Sayler is a past chair of the Environmental Protection Agency Board of Scientific Counselors, a former member of the Department of Energy's Biological and Environmental Research Advisory Committee, and a member of the Strategic Environmental Research and Development Program Advisory Board. He holds a PhD in bacteriology and biochemistry from the University of Idaho.

Deborah L. Swackhamer is a professor of science, technology, and public policy in the Hubert H. Humphrey School of Public Affairs of the University of Minnesota, codirector of the university's Water Resources Center, and a professor of environmental health sciences in the School of Public Health. She studies the processes that affect the behavior of and exposures to toxic chemicals in the environment and works on policies to address potential risks. In 2012, Dr. Swackhamer completed a 4-year term as chair of the Science Advisory Board of the US Environmental Protection Agency, and she is a member of the Science Advisory Board of the International Joint Commission of the United States and Canada. She recently served on the National Research Council Committee on Sustainability Linkages in the Federal Government. She is also a governor appointee to the Minnesota Clean Water Council. She was president of the National Institutes for Water Resources in 2011–2012. Dr. Swackhamer is a member of the Editorial Advisory Board of the journal *Environmental Science & Technology*. She is a fellow of the Royal Society of Chemistry in the UK. Dr. Swackhamer received the 2007 Harvey G. Rogers Award from the Minnesota Public Health Association. In 2009, she received the Founders Award from the Society of Environmental Toxicology and Chemistry for lifetime achievement in environmental sciences. She was the 2010 recipient of the University of Minnesota's Ada Comstock Award. She received a PhD in limnology and oceanography from the University of Wisconsin–Madison

Mark J. Utell is a professor of medicine and environmental medicine, director of occupational and environmental medicine, and former director of pulmonary and critical-care medicine in the University of Rochester Medical Center. His research has centered on the effects of environmental toxicants on the human respiratory tract. Dr. Utell has published extensively on the health effects of inhaled gases, particles, and fibers in the workplace and other indoor and outdoor environments. He was the co-principal investigator of an Environmental Protection Agency (EPA) Particulate Matter Center and former chair of the Health Effects Institute's Research Committee. He has served as chair of EPA's Environmental Health Committee and on the Executive Committee of the EPA Science Advisory Board. He is a former recipient of the National Institute of Environmental Health Sciences Academic Award in Environmental and Occupational Medicine. Dr. Utell is a member of the National Research Council Committee on a Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials. Previously, he chaired the Institute of Medicine (IOM) Committee on Review of the Department of Labor's Site Exposure Matrix (SEM) Database, the National Research Council Board on Environmental Studies and Toxicology and its Committee on Research Priorities for Airborne Particulate Matter, the IOM Committee to Review the Health Consequences of Service during the Persian Gulf War, and the IOM Committee on Biodefense Analysis and Countermeasures. Dr. Utell received an MD from Tufts University School of Medicine.

Appendix C

Presenters at the Committee's Information-Gathering Sessions

SEPTEMBER 17, 2013

A Strategic Context for Strengthening the EPA Laboratory Enterprise
Robert Perciasepe, EPA Deputy Administrator

Present and Future Considerations of the EPA Laboratory Enterprise and the Role of the NRC Committee
Glenn Paulson, EPA Science Advisor
Michelle Pirzadeh, EPA Region 10 Deputy Regional Administrator
Barry Pepich, director, EPA Region 10 Laboratory
David Haugen, director, Testing and Advanced Technology Division, EPA National Vehicle and Fuel Emissions Laboratory
Lek Kadeli, EPA Principal Deputy Assistant Administrator for Research and Development

Representatives of External EPA Advisory Groups: Perspectives on the EPA Laboratories
Katherine von Stackelberg, Chair, Board of Scientific Counselors
H. Christopher Frey, Chair, CASAC
Daniel Schlenk, Chair, FIFRA Scientific Advisory Panel

DECEMBER 16, 2013

Overview of ORD Research Laboratories
Robert Kavlock, EPA ORD
Jennifer Orme-Zavaleta, EPA ORD

Current and Future Considerations about the EPA Laboratory Enterprise and the Role of the NRC Committee
Glenn Paulson, EPA Science Advisor

EPA Intramural Laboratories and their Science Contributions
Barry Pepich, director, EPA Region 10 Laboratory
Lynnann Hitchens, EPA ORD
Dale Pahl, EPA Office of the Science Advisor

Cross-Organization Laboratory Collaboration: PCB's in Schools: A Tale of One City
Deb Szaro, EPA Region 2

Cross-Organization Laboratory Collaboration: The Emergency Response Laboratory Network
Greg Sayles, acting director, EPA/ORD National Homeland Security Research Center

Cross-Organization Laboratory Collaboration: Overview of the Office of Radiation and Indoor Air's National Analytical Radiation Environmental Laboratory (NAREL) Programs
John Griggs, EPA/Office of Air and Radiation

Cross-Organization Laboratory Collaboration: Deepwater Horizon Oil Spill Incident Response
David Neleigh, EPA Region 6

FEBRUARY 13, 2014

Aligning Laboratory Science Activities with EPA Strategic Goals
Robert Kavlock, Deputy Assistant Administrator for Research, ORD/EPA
Mark Hague, Deputy Regional Administrator, Region 7/ EPA
Rob Maxfield, Laboratory Director, Region 1/ EPA
Gregory Carroll, Office of Ground Water and Drinking Water, OW/EPA [National Water Program Guidance]
Joe Greenblott, Office of the Chief Financial Officer, EPA [Technical Guidance for National Program Managers]
Glenn Paulson, EPA Science Advisor

Overview of the EPA Laboratory Portfolio Analysis Process
Glenn Paulson, EPA Science Advisor

Molecular Method Solutions for Ambient Water Quality Assessment: A Collaborative Approach
Orin Shanks, National Risk Management Research Laboratory, ORD/EPA
Kevin Oshima, National Exposure Research Laboratory, ORD/EPA

Recommendations Provided in the U.S. Government Accountability Office Report (GAO-11-347), Issued in July 2011
Alfredo Gomez, Director, Natural Resources and Environment, GAO
Angela Miles, Senior Analyst, GAO

Perspectives on the EPA Laboratory Enterprise
Paul Anastas, former EPA Assistant Administrator for Research and Development

Perspectives on Interactions between the California Air Resources Board and EPA Labs
Bart Croes, Chief, Research Division, CARB

MARCH 10, 2014

Discussion of EPA Program Laboratories
Glenn Paulson, EPA Science Advisor
Mike Shapiro, Deputy Assistant Administrator for the Office of Water
Louise Wise, Deputy Assistant Administrator for the Office of Chemical Safety and Pollution Prevention
Carol Rushin, Director, National Enforcement Investigations Center, Office of Enforcement and Compliance Assurance

Appendix D

Relevant Findings and Recommendations From Previous Reports

This appendix presents relevant findings and recommendations from past reports of EPA's Board of Scientific Counselors, EPA's Science Advisory Board, National Research Council, and U.S. Government Accountability Office. In carrying out its study, the committee sought to build upon the results of these past reports as well as others cited in the chapters of its report.

1. Strengthening Science at the U.S. Environmental Protection Agency: Research-Management and Peer-Review Practices **(NRC 2000)**

Recommendation: The committee concurs with the recommendations of the 1997 report of its companion committee — the *Committee on Research Opportunities and Priorities for EPA* — that ORD should maintain approximately an even balance between core research and problem-driven research (p. 138).

Recommendation: The committee recommends that ORD place greater emphasis on maintaining awareness of research conducted by other organizations. ORD should develop and implement a proactive, structured, and visible strategy for stimulating, acquiring, and applying the results of research conducted or sponsored by other federal and state agencies, universities, and industry, both in this country and abroad (p. 139).

Recommendation: The committee recommends that ORD continue and expand its multiyear research planning approaches in both problem-driven and core research areas (p. 137).

Recommendation: The committee recommends that the National Center for Environmental Research, in concert with ORD's national laboratories, develop additional mechanisms to promote and facilitate research interactions among STAR grantees and ORD research staff (pp. 140-141).

Recommendation: The committee recommends that ORD substantially improve the documentation and transparency of its decision-making processes for setting research and technical-assistance priorities, making intramural and extramural assignments, and allocating funds (p. 143).

Recommendation: The committee recommends that the administrator direct the deputy administrator for science and technology to expand upon the agency's recently initiated science inventory by conducting, documenting, and publishing a more comprehensive and detailed inventory of all scientific activities conducted by agency units outside ORD. The results of the inventory should be used to ensure that such activities are properly coordinated through the agency-wide science-planning and budgeting process and are appropriately peer reviewed (p. 144).

Recommendation: The committee recommends that EPA change its peer-review policy to more strictly separate the management of the development of a work product from the management of the peer review of that work product, thereby ensuring greater independence of peer reviews from the control of program managers, or the potential appearance of control by program managers, throughout the agency (p. 145).

Recommendation: The committee recommends that the numbers and skill mix of the staff of ORD's National Center for Environmental Research be reassessed to ensure they are consistent with the needs of the current program of research grants, centers, and fellowships (p. 140).

Recommendation: The committee recommends that EPA substantially increase its efforts to disseminate actively ORD's research products and ongoing projects, to explain their significance, and to assist others inside and outside the agency in applying them (p. 141).

Recommendation: The committee recommends the establishment of a new position at EPA: deputy administrator for science and technology. This position would require authorization from Congress, appointment by the President, and confirmation by the Senate (p. 130).

Recommendation: To foster greater continuity in the management of EPA's research program, the committee recommends that the position of assistant administrator for ORD be converted to a statutory term appointment of 6 years (p. 132).

Recommendation: The committee recommends that ORD make a concerted effort to give its research managers a high degree of flexibility and accountability. They should be empowered to make decisions at the lowest appropriate management level consistent with EPA policy an ORD's strategic goals and budget priorities (p. 133).

Recommendation: The committee recommends that ORD continue to place high priority on its graduate fellowship and postdoctoral programs (p. 134).

Recommendation: The committee recommends that ORD create the equivalent of endowed academic research chairs in the national laboratories (p. 135).

2. The Measure of STAR: Review of the U.S. Environmental Protection Agency's Science to Achieve Results (STAR) Research Grants Program **(NRC 2003)**

Recommendation: EPA should continue its efforts to attract "the best and the brightest" researchers to compete for STAR funding (p.143).

Recommendation: The committee recommends that STAR and ORD continue to work to produce state-of-the-science and research-synthesis documents. These are important for identifying critical information gaps and communicating the state of knowledge on a particular issue to the many users and audiences interested in this information (p. 142).

Recommendation: Given the nation's continuing need for highly qualified scientists and engineers in environmental research and management, the STAR fellowship program should be continued and funded (p. 143).

Recommendation: STAR program funding should be maintained at 15-20% of the overall ORD budget, even in budget-constrained times. However, budget planners should clearly recognize the constraints of not having inflation escalators to maintain the level of effort of the entire program (p. 143).

3. ***Evaluating Research Efficiency in the U.S. Environmental Protection Agency*** **(NRC 2008)**

Finding: The key to research efficiency is good planning and implementation. EPA and its Office of Research and Development (ORD) have a sound strategic planning architecture that provides a multi-year basis for the annual assessment of progress and milestones for evaluating research programs, including their efficiency (p. 59).

Finding: All the metrics examined by the committee that have been proposed by or accepted by OMB to evaluate the efficiency of federal research programs have been based on the inputs and outputs of research management processes, not on their outcomes (p. 59).

Finding: Ultimate-outcome-based efficiency metrics are neither achievable nor valid for this purpose (p. 59).

Finding: EPA's difficulties in complying with PART questions about efficiency (questions 3.4 and 4.32) have grown out of inappropriate OMB requirements for outcome-based efficiency metrics (p. 59).

Finding: An "ineffective" (OMB 2007a) 3 PART rating of a research program can have serious adverse consequences for the program or the agency (p. 59).

Principle: The process efficiency of research should not be evaluated using outcome-based metrics (p. 61).

Principle: The efficiency of R&D programs can be evaluated on the basis of two metrics: investment efficiency and process efficiency (p. 62).

Recommendation 1: To comply with PART, EPA and other agencies should only apply quantitative efficiency metrics to measure the process efficiency of research programs. Process efficiency can be measured in terms of inputs, outputs, and some intermediate outcomes but not in terms of ultimate outcomes (p. 65).

Finding: The most effective mechanism for evaluating the investment efficiency of R&D programs is an expert-review panel, as recommended in earlier reports of the Committee on Science, Engineering, and Public Policy and the Board on Environmental Studies and Toxicology. Expert-review panels are much broader than scientific peer-review panels (p.60).

Principle: Investment efficiency is best evaluated by expert-review panels that use primarily qualitative measures tied to long-term plans (p. 63).

Principle: Process efficiency, which may be evaluated by using both expert review and quantitative metrics, should be treated as a minor component of research evaluation (p. 64).

Recommendation 2: EPA and other agencies should use expert-review panels to evaluate the investment efficiency of research programs. The process should begin by evaluating the relevance, quality, and performance of the research (p. 66).

Finding: Among the metrics proposed to measure process efficiency, several can be recommended for wider use by agencies (see recommendation 1) (p. 60).

Principle: Despite the wide variability of research activities among agencies, all agencies should evaluate their research efforts according to the same criteria: relevance, quality, and performance (p. 60).

Recommendation 3: The efficiency of research programs at EPA should be evaluated according to the same overall standards used at other agencies (p. 67).

4. <u>SAB Comments on EPA's Immediate Science Needs</u> **<u>(EPASAB 2009, pp. 2-3)</u>**

Finding: EPA has long worked with other organizations on environmental issues.

Recommendation: EPA should develop more robust partnerships and innovative approaches to supporting cutting-edge research and development, both domestically and internationally.

Finding: Human health and environmental problems are interrelated, are often associated with multiple stressors, and often involve exposures from more than one medium.

Recommendation: EPA should increase its efforts to address issue evaluation and management in an integrated manner that recognizes the complexity of the world in which the problems occur.

Finding: EPA has already begun to design a program to conduct integrated multidisciplinary research on complex environmental issues.

Recommendation: EPA should support new research frameworks to overcome barriers that now limit development of knowledge of integrated environmental problems and their solutions.

Finding: EPA must commit to establishing a research base that will make it possible for the nation to acquire the knowledge needed to address the difficult environmental problems that we now face and which will only grow in complexity and magnitude in the future

Recommendation: EPA should move to restore the budget for research and development in order to maintain the U.S. as an international leader in environmental protection.

Finding: Decision, Behavioral and Social Sciences are critical to framing, designing and implementing EPA decision processes and to the effective and credible resolution of environmental problems.

Recommendation: Research and operational capacity in the social sciences should be augmented.

Finding: Energy and climate change issues stand out in their importance to the nation's and the world's well-being.

Recommendation: EPA should take the lead in assessing the environmental and health implications of energy and climate change policies.

5. <u>Computational Toxicology Review</u> **<u>(EPABOSC 2010)</u>**

Finding: The BOSC members believe that the CTRP has made substantial progress toward meeting the original long-term goals, and that the progress is appropriate given the duration of the Program's existence and the resources involved (p. 2).

Finding: One of the challenges that the CTRP has taken on is the assembly and integration of the vast quantities of existing, available toxicological and toxicogenomics data (p.2).

Recommendation: These projects need to continue to build on things that are in place, drilling deeper into the data and continuing the problem of structuring, standardizing, and organizing the data so that they can be more easily subjected to comprehensive meta-analyses (p.3).

Recommendation: Several CTRP projects have undertaken structuring, standardizing, and organizing the data so that they can be more easily subjected to comprehensive meta-analyses. At this point, the CTRP should obtain some public feedback on how people are using and interpreting the available data (p. 5).

Finding: A major part of the modeling effort focuses on interrogating the databases. The BOSC noted that a substantial part of these efforts utilizes machine-learning methods (p. 4).

Recommendation: BOSC encourages the Program to consult with biostatisticians early and often to assure they can address any objections [to machine learning]; the CTRP also should consider attempting some additional methods (p. 4).

Finding: There also is a need to interact more extensively with the broader scientific user community in the process of developing and rolling out tools and software (p. 4).

Recommendation: This could be achieved through an annual or biannual conference by bringing together the data generators, the data users, and the risk assessors/managers—the ultimate users of these alternative methods/models (p.4).

Recommendation: Acceptance of products, methods, and databases by the risk assessment community is the key to success. Hence, the NCCT should organize an annual or biannual conference that brings together the data generators, data users, and risk assessors/managers—the ultimate users of these alternative methods/models (p. 5).

Finding: There were concerns expressed by some BOSC members that associations are not causation and this should be recognized by the EPA management, both at the CTRP level and at the level of the Office of the Administrator (p. 4).

Recommendation: The results of a computer-generated association should be carefully examined through traditional testing and careful scientific study (p. 4).

Recommendation: As more data from high-throughput assays and computer models become available, the NCCT should provide guidance on how to interpret this information in the context of more traditional testing and scientific examination so that risk assessment practitioners in the EPA program offices can apply these findings (p. 5).

Recommendation: Continue to interact with other scientific bodies, regulatory agencies, and universities both in the United States and globally so as to insure that work conducted elsewhere can be "built upon." In addition, it is recommended that the group interact with the toxicology groups within pharmaceutical and major chemical companies (p. 7).

Recommendation: Routinely (perhaps biannually) sponsor some sort of exchange of information with risk assessment practitioners both inside and outside EPA (corporations, consultants, and government scientists) to be sure that the end products of the Program's work are both reliable and of use to the future users (p. 7).

Recommendation: For the next BOSC review, develop a table that presents the level of effort dedicated to specific projects, by year. This table would contain the number of CTRP FTEs, as well as the approximate level of "collaborative" effort (from other EPA laboratories and other partners and consultants). In kind support and "hard" dollars also should be presented (p.7).

Recommendation: Keep the statisticians and mathematical modelers involved in assay evaluation so that they can move from qualitative prediction to quantitative prediction of outcomes from exposure data (p. 8).

Recommendation: Conduct an unbiased evaluation of the usefulness of particular assays to achieve prediction beyond a single class of compounds and to define knowledge gaps for new assay design (p.9).

Recommendation: Develop case studies that demonstrate a strategy for incorporation of CTRP tools/research into the risk assessment process (p. 9).

Recommendation: Be more integrative, both internally and externally, to ensure all parties are working from common assumptions, data development schedules, and deliverable planning (p. 10).

Recommendation: Expand outreach to the broader community, both within EPA and in the extramural community. This is not to say that the CTRP has not been effective in building a strong outreach program, but only that this needs to be a priority, and possibly a higher priority (p. 13).

Recommendation: Detail specific roles for the STAR Centers as part of the integrated approach to managing the Program's mission (p. 13).

Recommendation: Place a higher priority on incorporation of ecological receptors and greater focus on assessment of exposure factors (p. 13).

Recommendation: Develop a forward, longer term plan to incorporate the field of ecological risk assessment as part of the CTRP (p. 13).
Recommendation: Expand the ExpoCast program to include real exposure and outcomes data, as well as the additional development of software resources to take advantage of these data for exposure and outcome predictions. This should be a priority of the Center (p. 13).

Recommendation: Continue training postdoctoral fellows because these scientists have the potential to be ambassadors to the rest of the community to help extend the understanding and acceptance of the types of computational tools the CTRP is trying to develop, and in doing so, ultimately help to improve those tools and their efficacy (p. 13).

Recommendation: Highlight quality assurance for software and models with a specific testing approach augmented with a sophisticated evaluation approach that probes how the systems produced work in the hands of users (p. 13).

Recommendation: Promote "user-centered design", an approach that grounds the process of design in information about the people who will use the product (p. 13).

Recommendation: Establish performance metrics that track the development of tools and resources for informing chemical prioritization, toxicity testing, and risk assessment (p. 15).

Recommendation: Continue to meet with customers, clients, and stakeholders on a regular basis to ensure that the Program is meeting the needs of the risk assessors and risk managers in the Agency (p. 15).

***6. ORD Strategic Research Directions and Integrated Transdisciplinary Research* (EPASAB 2010)**

Finding: ORD's research direction largely misses strategic opportunities related to social and behavioral sciences. It also misses the opportunity to improve ORD research programs by incorporating social and behavioral sciences (p.5).

Recommendation: EPA needs to reorient its research agenda to recognize that many environmental threats stem from the actions, decisions, and behaviors of individual Americans (p.6).

Finding: Due to the nature of the challenges and scientific capacity within EPA, there is strong justification for EPA to provide leadership in establishing multi-agency partnerships that leverage resources and provide comprehensive solutions (p. 6).

Finding: There is no systematic communication between ORD and states regarding research needs (p.3).

Recommendation: A more systematic process is needed for states and tribes to identify, organize, prioritize and communicate their immediate and anticipated requirements for science support into the ORD research planning and implementation process (p. 3).

Finding: ORD's management structure currently provides the ORD Executive Committee and Laboratory Directors with primary control of resources, while research planning is the responsibility of National Program Directors (p. 5).

Recommendation: Integrated transdisciplinary research requires alignment of research resources with Agency priority needs and is more likely to succeed with true matrix management that recognizes those priorities and addresses resource allocation decisions (p. 5).

Finding: ORD demonstrated linkages between ORD research contributions and EPA accomplishments under the key priorities (p. 3).

Recommendation: We recommend that EPA make these linkages when planning future research programs (p. 3).

Finding: It will be essential for EPA as a whole, and not just ORD alone, to adopt a systems approach to research planning (p. 3).

Recommendation: A systems approach that incorporated human health concerns into global change analysis could be used to break down artificial barriers between human health and ecological assessment (p.4).

Recommendation: Systems approaches, if applied to air research or to ORD's "one hydrosphere" vision, could help EPA better understand the root causes of environmental problems that may be related to energy usage, transportation, and local planning and zoning (p. 4).

Finding: Planning and conducting a systems-based and integrated transdisciplinary research program requires mechanisms to encourage scientists to think outside their traditional disciplines or research programs, to seek connections and questions that cross research programs and media, and to look for "systems effects" related to a research question (p.5).

Recommendation: We recommend that ORD consider and implement as soon as possible strategies to 1) encourage systems approaches to research and, 2) support and provide leadership for integrated transdisciplinary research teams (pp. 4-5).

7. ***The Use of Title 42 Authority at the U.S. Environmental Protection Agency: A Letter Report*** **(NRC 2010, pp 23-24)**

On the basis of its evaluation and review, the committee offers the following findings and recommendations:

The committee agrees with previous expert panels and committees that a science and engineering workforce that is capable of performing and conducting research at the highest level is essential for EPA to protect public health and the environment.

On the basis of the committee's review of ST, SL, and SES positions, the committee concludes that no other hiring mechanisms or authorities available to EPA serve the function of Title 42 to recruit and retain world-class scientists and engineers.

The selection of particular research fields that would benefit most from Title 42 appointments is of paramount importance. The committee recommends that ORD focus its Title 42 appointees in fields deemed most critical by its research priority-setting process.

The committee notes that the number of Title 42 appointments is not limited at NIH and CDC, other federal agencies that fill scientific positions using Title 42 authority. The numbers of Title 42 appointments in those agencies are substantially larger than at EPA.

All world-class scientists and engineers do not necessarily have doctoral-level degrees, and EPA should be flexible in its requirement that all Title 42 appointees have such degrees.

EPA has approached the use of Title 42 authority prudently. For example, a position was not filled when highly qualified candidates could not be identified, and EPA has not awarded the maximum compensation allowed under Title 42 to appointees. The committee concurs with EPA's approach.

In developing its Title 42 program, EPA has used various techniques to recruit candidates. To identify the most qualified candidate, the committee recommends that EPA adhere to the following procedure: (1) establish a search committee to oversee recruitment, promote diversity in the process, evaluate applicants' credentials, and recommend the most qualified applicants to a selection committee; (2) advertise widely on appropriate Web sites, in appropriate journals, through scientific and engineering societies, and by contacting highly competent people in the relevant disciplines; and (3) form a selection committee to determine the best candidate and forward the recommendation to ORD management, ultimately the ORD AA or designee, for approval. Both search and selection committees should include members who are outside EPA. The entire search and selection process should be as open as feasible to ensure that the best practices are followed, that a broad and diverse search has reached the most qualified potential candidates, and that fairness prevails.

The Title 42 program at EPA is small and still evolving, but it has worked well. Outstanding candidates have been identified and hired, and top scientists have been retained. Furthermore, the BOSC and EPA indicate that the Title 42 program has helped the agency to achieve its mission. For example, the NCCT has, in its few years of existence, conducted important research and made substantial progress in developing new tools based on advances in molecular biology and genomics.

The committee recommends that permanent Title 42 authority be granted to EPA.

The committee recommends that EPA use the BOSC or the SAB to review the Title 42 program every 5 years to ensure that it is being used for the intended purposes of creating a critical mass of world class scientists and engineers, that Title 42 hires are in the fields identified as having the highest priority by the agency, and that it is implemented in a manner that ensures selection of the best candidates.

The committee recommends that EPA be granted expanded authority to define the number of Title 42 positions on the basis of its programmatic needs and available budget.

***8. <u>To Better Fulfill Its Mission, EPA Needs a More Coordinated Approach to Managing Its Laboratories</u>* <u>(GAO 2011, pp. 27-28)</u>**

<u>EPA labs: function and capabilities for meeting current needs</u>

Recommendation: Improve physical infrastructure and real property planning and investment decisions by:

managing individual laboratory facilities as part of an interrelated portfolio of facilities;

ensuring that master plans are up-to-date and that analysis of the use of space is based on objective benchmarks; and

improving the completeness and reliability of operating-cost and other data needed to manage its real property and report to external parties.

<u>EPA Labs Management Process</u>

Recommendation: Develop an overarching issue-based planning process that reflects the collective goals, objectives, and priorities of the laboratories' scientific activities.

Recommendation: Establish a top-level science official with the authority and responsibility to coordinate, oversee, and make management decisions regarding major scientific activities throughout the agency, including the work of all program, regional, and ORD laboratories.

Recommendation: If EPA determines another independent study is needed, the agency should include alternative approaches for organizing the laboratories' workforce and infrastructure, including options for sharing and consolidation.

<u>EPA Labs Ability to Meet Future Challenges</u>

Recommendation: Develop a comprehensive workforce planning process for all laboratories that is based on reliable workforce data and reflects current and future agency needs in overall number of federal and contract employees, skills, and deployment across all laboratory facilities.

9. ORD New Strategic Research Direction (EPASAB/BOSC 2011)

EPA science needs (challenges); future

Recommendation: One area where ORD can increase its capacity to address future critical environmental issues involves the exploration of opportunities offered by computational analysis and modeling of complex environmental data (p.10).

Finding: Sustainability goals and all the systems of interest to EPA include human behavior (p. 12).

Recommendation: Increased emphasis on social, behavioral and decision sciences within ORD is needed for the new research programs to be successful. Social science research should be integrated in all of the programs in explicit ways. (p. 12).

EPA labs: function and capabilities for meeting current needs

Recommendation: It would be helpful for all research frameworks to include a list of definitions of key sustainability terms that would be consistent across ORD's programs (p. 5).

Recommendation: SAB and BOSC recommend that ORD revise each [of the six] research frameworks to include sustainability explicitly in its research vision, invoke a definition of sustainability shared across ORD, and demonstrate clearly how planned research relates to the key components of sustainability (the environment, the economy, and society) (p. 6).

Extramural Research funded by EPA

Recommendation: ORD should set defined goals to catalyze and complement environmental science programs outside EPA and seek BOSC review and assessment related to this topic every two years. (p.10)

Recommendation: Innovation could be enhanced by emphasizing innovation in EPA's extramural grant programs and by making EPA data easily accessible to the outside community of scientists who could use these data in creative ways (p. 11).

Recommendation: The SAB and BOSC recommend that ORD explore mechanisms for industry-government collaboration (p. 27).

Recommendation: ORD should evaluate existing mechanisms for inter-agency collaboration and build on them to maximize the potential to catalyze and complement environmental science programs outside EPA (p. 23).

Recommendation: ORD should explore new opportunities to partner with the National Science Foundation to support extramural research in [the social science] area, such as the Foundation's Sustainability Research Networks Competition (SRN) and its Dynamics of Coupled Natural and Human Systems (CNH) program (p. 17).
Recommendation: ORD should consider programs to sponsor senior academic researchers for one-year visiting sabbaticals to seek their suggestions about how to transform the Air, Climate and Energy program into a program fully integrating sustainability (p. 21).

Recommendation: The Homeland Security model of coordination within and outside the EPA can be a model for other research programs (p. 30).

EPA Labs Management Process

Finding: The increase in the amount of communication among ORD's National Program Directors and Directors of Laboratories and Centers in the development of ORD's research frameworks is readily apparent and very positive (p. 4).

Recommendation: ORD should seek to expand formal mechanisms to promote networking among internal researchers to improve research coordination throughout the research process in the least time-intensive manner (pp. 4-5).

Recommendation: ORD should identify priority cross-program research topics such as nitrogen and climate as vehicles for research coordination and building of interdisciplinary culture (p. 5).

Recommendation: Regarding prioritizing programs for increased or decreased emphasis, the SAB and BOSC recommend that ORD conduct analyses to help develop criteria for prioritization (p. 26).

EPA Labs Ability to Meet Future Challenges

Finding: ORD's involvement of stakeholders in EPA program and regional office and other federal partners in research planning provides a good mechanism to identify environmental issues and prioritize among them (p. 9).

Recommendation: It may be helpful for ORD to form an internal committee of cross-program futurists, with representatives from each research program to identify emerging issues and to consult regularly with the SAB, BOSC and other EPA groups and external stakeholders (p. 9).

Finding: The EPA has thought seriously and operationally about ways of energizing the creative nature of ORD scientists and has begun to explore ways of enhancing innovation as a fundamental part of ORD programs (p. 11).

Recommendation: ORD should develop metrics to evaluate the contributions of the Chief Innovation Officer and programs such as Pathfinder. ORD should define "failure" and "success" as it further develops its innovation program and reach agreement on an acceptable failure rate for innovation efforts (p. 11).

Recommendation: The SAB and BOSC recommend that ORD undertake research to define the benefits of moving from a more technology-based regulatory system to a performance-based regulatory system that provides incentives for sustainable solutions (p. 21).

EPA Labs Leadership in Environmental Research and Other Science-Related Activities

Recommendation: ORD should continuously stimulate interactions between EPA and outside scientists. One mechanism could involve a program of roundtables with outside experts. Visiting scientists could be brought into the laboratories and centers for longer periods (e.g., one year) to cross-fertilize ideas on how to make sustainability an organizing principle at EPA (p.10).

***10. Science Integration for Decision Making at the U.S. Environmental Protection Agency* (EPASAB 2012)**

Finding 1a: Over 6,000 EPA employees are involved in scientific assessments, research, and related activities, with approximately 1,300 full-time scientific staff in the Office of Research and Development (ORD) and approximately 4,700 full-time scientific staff in program and regional offices (p.2).

Finding 1b*:* An overarching barrier to consistent science integration is the lack of strong, coordinated management at EPA to support the scientists in the regional and program offices. Currently, the EPA does not have a single entity responsible for managing and strengthening EPA's scientific workforce so that it functions as a resource for the agency as a whole (p.8).

Finding 1c: The EPA has not developed a coordinated human resource strategy for building this science base within ORD and beyond. Effective science integration requires the recruitment, retention, and development of leading scientists from many fields across EPA programs and regions, as well as in ORD (p. 8).

Recommendation 1: The EPA should increase and improve support and training for scientists and managers across the agency, especially in programs and regions, to strengthen capacity for science integration. Traditional rewards and recognition for scientific excellence focus on discovery, peer reviewed publication, and national and international recognition by peers. As a result there are few professional incentives for scientists to focus on support of regulatory decision making. The SAB recommends that scientists throughout the agency be encouraged to participate actively in developing improved approaches to integrate science into agency decisions and be rewarded for their valuable contributions (p. 11).

Finding 2a: Science integration practices vary across the agency. Some managers actively promote science integration, but more could be done in most program and regional offices. Time and resource constraints are important barriers to science integration across the EPA, but notably some leaders and managers make science integration a priority. The need for improving science integration is most acute in the regions and program offices on the front line for addressing environmental issues. Currently, the EPA does not have a single entity responsible for managing and strengthening the EPA's scientific workforce so that it functions as a resource for the agency as a whole (pp.7-8).

Recommendation 2: Managers should be engaged in and accountable for integrating science into decision making, starting with problem formulation and science assessment, in their own organizations and across the EPA. The SAB recommends that EPA managers consistently devote attention to implementing all the components of science integration. Management should be accountable for problem formulation to martial integrated thinking about complex environmental problems as they occur in the real world (p.10).

Finding 3a: Science integration is an integral component of many decisions at EPA. The SAB interviews confirmed that agency staff and managers view science as an important component of decision making at the EPA, whether decisions involve regulatory, enforcement or voluntary programs. Science Integration is a three-part process:

1) problem formulation – asking the right questions;
2) assessment – combining information and analyses from different scientific fields to address the problem; and
3) decision making and evaluation – application of the science and ongoing evaluation of the outcome of the decision (pp. 3-4).

Finding 3b: No EPA program has fully implemented all the steps of science integration. The SAB envisions a framework for science integration with three major components: problem formulation; analysis and decision making; and implementation and performance evaluation. The first step, problem formulation, may be the most important. Problem formulation is a systematic planning step, linked to the regulatory and policy context of an environmental problem, which identifies the major factors to be considered, developed through interactions among policy makers, scientists and stakeholders. The analysis and decision-making step often includes the assessment of existing science (p.4).

Finding 3c: ***Regulatory program and disciplinary "silos" remain significant barriers to science integration.*** Narrow interpretations of legislative mandates and the organizational structure of the EPA's regulatory programs often have posed barriers to innovation and cross-program problem solving. Rigidity within scientific disciplines also can pose an obstacle to science integration. Interdisciplinary work is difficult; experts often use different terminology and methodologies. These differences can become intellectual silos when the science integration is not formally facilitated (p. 5).

Finding 3d: ***There is a critical need for more high quality assessments translating existing science on a broad range of topics important to decision making at the EPA.*** Regional and program offices emphasized the importance of science assessments that evaluate the state of existing science. However, interviewees noted that scientific literature reviews published in peer-reviewed journals generally do not provide assessment information that meets the EPA's regulatory needs. The EPA has a continuing need to develop capacity for trans-disciplinary scientific assessment, translation, and integration (the cover letter).

Recommendation 3: ***The EPA should explicitly plan for science integration to support environmental decisions.*** For each decision requiring scientific information, science integration will require an initial problem formulation step, with the following components:

1) Involvement of the responsible decision-maker to define the initial questions that will look broadly at the physical, economic, and social context of specific environmental problems;
2) Identification of options for intervention and risk management;
3) An assessment plan that discusses the appropriate level and types of science required for the decision;
4) Expectations regarding the required timeline and resources; and
5) An appropriate balance of public and stakeholder engagement (p.9).

***11. Implementation of ORD Strategic Research Plans* (EPASAB/BOSC 2012)**

EPA science needs (challenges): current

Sustainability (p. 4)

Recommendation: Each ORD program should define more specifically what sustainability means within the program context, and identify how each plan incorporates ecological and human health into the definition of sustainability.

Recommendation: ORD should collaborate with other partners in the EPA, including the National Center for Environmental Economics, to develop a plan to develop the social, behavioral and decision science needed to support sustainability research and other goals identified in ORD's six major research programs. A useful first step would be for ORD to plan a workshop on this topic and seek SAB and BOSC advice in workshop planning.

Extramural Research funded by EPA (p. 9)

Recommendation: ORD should use solicit and support innovation research projects in communities and utilities across the country.

EPA Labs Management Process

Recommendation: ORD should consider including a more detailed timeline with deliverables for planned activities for each research program with specific milestones and/or intermediate deliverables (p. 3).

Recommendation: ORD should develop individual "roadmaps" with goals and an outline of paths to those goals for each of the integrated research topics, similar to the roadmap being developed for ORD's nitrogen topic (p. 6).

Recommendation: ORD should develop a graphical framework for each integrated research topic that identifies and discusses the responsibilities and relationships of the various participating EPA programs and external agencies and groups (p. 6).

[see also individual ORD program recommendations below]

EPA Labs Ability to Meet Future Challenges

Recommendation: In future action plans, ORD should provide a comprehensive mapping of projects to goals, and *not just provide examples* [emphasis added] (p. 3).

Recommendation: ORD should develop a structured approach (e.g., through a risk portfolio or decision science-based analysis) to assess the relative priorities of emerging issues vis à vis existing and legacy research activities (p. 5).

Recommendation: ORD should make training and development for ORD staff a priority and seek new ways to interact with scientists outside the EPA through partnerships with other agencies and academic institutions to keep staff on the frontier of science and alert to emerging issues (p. 5).

Recommendation: ORD should strive wherever possible to craft its research such that it fulfills the dual goals of meeting specific programmatic goals while also maintaining and expanding the agency's core capabilities in critical research areas (p. 5).

Innovation (p. 9)

Recommendation: When assessing potential innovation projects and impacts of innovation projects, ORD should consider multiple benefits of such projects, and identify and focus its metrics on the goals of the EPA's organizations and their specific need rather than on conventional business performance metrics.

Recommendation: Innovative activities and support of those activities should be prioritized to reflect the EPA's most pressing needs.

Recommendation: ORD should provide more information on the guiding principles that govern how Pathfinder Innovation Projects grants are awarded and how questions for challenges are chosen.

Recommendation: ORD should undertake additional efforts to identify and leverage the top innovators via mentoring of others and/or assembling the top innovators in small teams to promote further breakthroughs.

Recommendation: ORD should provide as much encouragement for social and sociotechnical innovations as for purely technological ones.

Recommendation: ORD should develop an award system that would align with the desired behavioral changes in moving the ORD culture to one of innovation.

Recommendation: ORD should sponsor a focused workshop on metric development for innovation that would result in a set of metrics that represents a reasonable fit with the ORD mission and desire for innovation.

Air, Climate, and Energy Program (p.12)

Recommendation: ORD should more explicitly map the long list of individual projects and project outputs in the Strategic Research Action Plans to strategic research themes and the overarching vision.

Recommendation: The Strategic Research Action Plan should include a plan for energy research and indicate how this research will integrate with the plans for climate and air quality research.

Recommendation: To support this additional systems-level focus on energy, ORD should identify senior leadership to provide necessary systems science expertise and ensure that the connections between energy research projects are drawn and made explicit.

Recommendation: The Strategic Research Action plan should include a description of how ORD's ACE activities are positioned within the portfolio of other research activities at the EPA and the research of other federal agencies.

Recommendation: The Strategic Research Action Plan needs more comprehensive and greater depth in planned social science and behavioral research.

Chemical Safety for Sustainability Program (p. 17)

Recommendation: Clearly demonstrate how CSS research impacts upon end users (e.g., risk managers, policy makers) and how it brings value for informing decisions.

Recommendation: Increase focus on the refinement and verification of proximal and consumer exposure models, including both external and internal dosimetry.

Recommendation: In the effort to transition toward EDSP21, place greater attention on the challenges involved in using reductionist approaches (e.g., ToxCast) in evaluating highly integrated physiological networks, such as the endocrine system.

Recommendation: Frame the research on EDSP21 as a precedent for addressing analogous challenges for evaluating other complex integrated biological systems (e.g., nervous system).

Recommendation: Define ORD's unique niche within the broader landscape of nanotechnology research.

Recommendation: Clearly and transparently describe the proposed approach for verification of new computational toxicology tools for their intended purpose and with respect to risk assessment, and present to BOSC for review.

Recommendation: Define the typical range of intra- and inter-individual variation in biological control pathways in order to distinguish between adaptive vs. adverse changes. Address how the program will dovetail with higher tier targeted testing.

Recommendation: Place greater emphasis on integration of toxicokinetics (ADME) and physiologically-based pharmacokinetic models.

Human Health Risk Assessment Program (pp. 25-26)

Recommendation: The EPA should broadly examine the diverse venues where risk assessment activities reside within the agency and seek to establish connections and integration that will foster ongoing enhancement of methodologies that are common to risk practitioners throughout the Agency.

Recommendation: ORD leadership should elaborate a strategic vision that enhances linkages among the thematic areas of the HHRA and with the other research programs, particularly the CSS program, and that emphasizes the way that the HHRA program contributes to sustainability research. This vision will be needed for revising the HHRA strategic plan.

Recommendation: A wide- reaching plan is needed for incorporating data from emerging technologies, e.g., "omics" and high throughput testing, into EPA risk assessment approaches and for evaluating the utility of these data for decision-making. This activity needs emphasis in Theme 4.

Recommendation: While progress by HHRA has been on pace during its first year, the agenda needs to be set for the longer-term with priorities given to the most critical topics for decision-making, particularly as resources may decline.

Recommendation: Exposure sciences need greater emphasis within the activities of the HHRA and further expertise is needed in this cross-cutting area.

Recommendation: The addition of further social, behavioral, and decision scientists to HHRA would benefit many of its activities and enhance integration with other programs. This recommendation echoes prior reports and speaks to the broad, multidisciplinary nature of decision-making and communication with regard to risk in the face of uncertainty. Long-standing gaps in expertise within the Agency should be addressed.

Recommendation: Concerted and sustained efforts are needed to assure that scientists with HHRA and elsewhere in EPA and decision-makers are fully versed in the latest risk assessment approaches and the interpretation and application of their findings.

Recommendation: EPA risk managers should also be educated about new data and approaches to risk assessment, leading to greater confidence in decisions based on these approaches. They need to be kept aware of advances made under Theme 4.

Recommendation: Peer reviews of HHRA documents and assessments could be made more efficient. The plans for changes in the IRIS assessments should benefit the peer review process. Additionally, the intensity of peer review should reflect the complexity and importance of the product. For extensive peer reviews, it is important to evaluate and improve the process to triage comments so that effort is directed at the points of criticism that are most important and that have significant implications for overall risk estimates and decision-making. This may be facilitated by an independent "monitor" or "editor."

Safe and Sustainable Water Resources Program (p. 29)

Recommendation: ORD should include specific tasks and milestones in the SSWR Strategic Research Action Plan.

Recommendation: The SSWR program should further clarify what is the agency's focus vs. the focus of other agencies regarding SSWR sustainability-related research.

Recommendation: The SSWR program should develop a structured way to assess emerging issues in establishing priorities.

Recommendation: The SSWR program should consider the magnitude and distribution of risks associated with not pursuing emerging SSWR research issues that could benefit certain communities such as environmental justice communities.

Recommendation: ORD should transparently communicate its efforts to prioritize research and conduct outreach and actively engage with communities when developing SSWR research priorities.

Recommendation: EPA should invest more in assessing use of market mechanisms for nutrient control, and identify metrics for nutrient management.

Recommendation: The SSWR program should be engaged with and knowledgeable about research on mechanisms and forms of nutrient delivery in agriculture.

Recommendation: ORD should identify and seek opportunities for leveraging research related to nutrients with other federal agencies and utilize ORD's strengths in areas such as monitoring, data analysis, and modeling within such leveraged efforts.

Recommendation: ORD should assess and encourage opportunities for innovation in nutrient research.

Recommendation: The SSWR program should take a leadership role in conducting green infrastructure research and incorporate natural infrastructure into its research.

Recommendation: The SSWR program should inventory best practices and innovation activities, and seek partnership opportunities to assess lessons learned related to green infrastructure.

Recommendation: The SSWR program should develop tools to encourage/improve how states help communities address Combined Sewer Overflow consent order requirements.

Recommendation: ORD should support competitions that solicit innovation in storm water monitoring and modeling.

Homeland Security Program (p. 32)

Recommendation: ORD should develop metrics for measuring progress and success at project conception.

Recommendation: The HSRP should document its impact by identifying the multiple benefits of its products. It should concurrently expand its communication about the broad applicability and many benefits of HSRP products and expertise; outline the value proposition to stake-holders; and market HSRP expertise to additional partners to increase resource leveraging.

Recommendation: The HSRP, as a valuable national resource, should adopt an "all-hazards" approach to enhance its value. Current products should be assessed and mapped to the needs of potential new partners. HSRP is strongly encouraged to conduct research portfolio analysis and road mapping to elucidate their current and future research needs.

Recommendation: HRSP should continue to enhance its relationships with other federal agencies where there is synergy.

Sustainable and Healthy Communities Program (pp. 38-39)

Recommendation: Integrating ecological and human health. The SAB and the BOSC commend EPA for recognizing the importance of bringing together human health and ecosystem services. Although this integration requires considerable effort, it is an important area that is worthy of investment. Moreover, EPA is the one agency that is positioned to do this. Although the communication flow among the different experts (e.g., ecosystem scientists and, human health scientists) does not always occur at the level needed, ORD is attempting to foster these interactions. Sustained efforts to promote interaction and integration are needed. ORD should outline the barriers to this integration and think creatively about strategies to help overcome them.

Recommendation: Inclusion of social, behavioral and decision sciences. Social, behavioral and decision sciences are an essential component of the SHC program because they contribute to understanding human actions driving environmental, social and economic change, the value of ecosystem services, development of decision-support tools, the design of policies, and behavioral responses to policy changes. SHC has taken a step in the right direction but much work remains to be done. The SAB and the BOSC would like to see future efforts expanded.

Recommendation: Distinguishing research from implementation. Throughout the action plan, it was difficult to separate (a) research from implementation, and (b) client from partner from community. The SAB and the BOSC suggests that SHC articulate more clearly its plan for research and how this plan fits in terms of interacting with local communities, state environmental agencies, and regional offices, and distinguish research from implementation in the text.

Recommendation: Focusing the science questions and research. There was some concern that there were too many science questions, with most too broad in scope. The SAB and the BOSC recommend that the Strategic Research Action be edited to explain how each of these science questions will be answered given the research that will be undertaken. This task would help SHC bring its stated research objectives into sharper focus, especially in light of resource constraints. The SAB and the BOSC also recommend that, at the very least, the program should prioritize the science questions.

Recommendation: Engaging communities and building partnerships. The SAB and the BOSC commend the SHC program for engaging stakeholders in community listening sessions. However, more structured and guided methods will allow for a better understanding of community values, needs/wants, and constraints. There also remained some confusion about what SHC means by community engagement. The SHC program should clarify its view of what community engagement, participatory research, and community self-assessment mean for the program. The SHC program should draw upon the previous work in this area.

12. Best Practices in Assessment of Research and Development Organizations (NRC 2012a)

WHAT CONSTITUTES AN EFFECTIVE R&D ORGANIZATION? (pp. 21-22)

- A clear and substantive mission,
- A critical mass of assigned work,
- A highly competent and dedicated workforce,
- An inspired, empowered, highly qualified leadership,
- State-of-the-art facilities and equipment,
- An effective two-way partnership with customers,
- A strong foundation in research,
- Management authority and flexibility, and
- A strong linkage to universities, industry, research institutes, and government organizations.

SOME QUESTIONS TO CONSIDER DURING ASSESSMENT (pp. 9-10)

Assessing Management

Answers to the following questions will be useful in the assessment of organizational management:

Does the organization's management understand its mission and its relationship to that of its parent? Does the vision statement of the organization align with that of the parent organization?

Is there a long-range plan for implementing the strategy by specific technical programs?

Does the organization have an explicit strategy for its work and for securing the necessary resources?

Do the program plans reflect a model for balance—that is, amount of basic versus applied and development research, and short-, medium-, and long-term work?

Does the organization have a clear champion within the parent organization?

Does management have an aggressive recruiting plan with well-defined criteria for new hires? Is there a set of practices for retaining, promoting, and recognizing the staff?

Does the organization have a process for forecasting likely future technical developments in areas appropriate to its mission?

Does the organization's management have discretionary authority to invest in new programs on its own initiative? Does management solicit ideas from the staff for new work?

Does management regularly assess facilities and equipment for adequacy? Does it have a fiscal plan for updating or replacing laboratory equipment?

Is there a process for regularly reviewing the organization's research portfolio for its alignment with the mission?

What is the management climate, and how does one assess it? Is there enough flexibility to work across organizational lines?

How does the structure of the organization support its mission?

How much collaboration is there with outside organizations? How many staff exchanges are there?

Does management have a well-defined process and criteria for determining what work is performed in-house versus what work is sponsored via grants, contracts, or other mechanisms with external entities?

Does the management support a culture of creativity, diversity, and entrepreneurship?

Assessing the Quality of Scientific and Technical Work

Answers to the following questions will be useful in the assessment of the quality of an organization's technical work:

Does the assessment include the quality of the staff, equipment, and facilities?

Does the assessment include the nature of the research portfolio as to alignment with the mission and the balance in regard to basic, applied, and development work and short-, intermediate, and long-term research?

Does the organization have a set of indicators that can serve as parameters when the time frame precludes immediate assessment? Does the organization benchmark itself against premier organizations?

Who is the expected audience for the assessment?

Is the review done by technical peers?

What are the criteria for ensuring the credibility and validity of the assessment?

What is the scope of the assessment? Does it include proposals for new work? Does it include assessment of completed work—internal review and authority to release a report, publications, patents, invited lectures, awards, and the like?

Who designs and manages the assessment?

Assessing Relevance and Impact

Addressing the following questions will be useful in the assessment of an organization's relevance and impact:

Does the organization have a process for identifying its stakeholders and customers?

Does it have a regular process for reviewing its programs and plans with its stakeholders?

Does the organization have a process for learning of its customers' current and likely future needs and expectations for the organization?

Does the organization have an explicit process for tracking the utilization of its results (e.g., is transition to the next R&D stage actively managed and measured)?

Does it have a formal program for recording the history of its work from concept to final utility or impact?

Does the organization have a program to conduct retrospective studies of its earlier work?

13. Science for Environmental Protection: The Road Ahead (NRC 2012b)

Finding: EPA can maintain its global position by staying at the leading edge of science (p. 10).

Finding: Effective science-informed regulation and policy aimed at protecting human health and environmental quality rely on robust approaches to data acquisition, modeling, and knowledge development (p. 8).

Finding: Maintaining leading-edge science requires the development and application of systems-level tools and expertise for the systematic analysis of the health, environmental, social, and economic implications of individual decisions (p. 10).

Recommendation: Maintaining leading-edge science requires the development of tools and methods for synthesizing scientific information and characterizing uncertainties. It should also integrate methods for tracking and assessing the outcomes of actions (that is, for being accountable) into the decision process from the outset (p. 10).

Finding: Although EPA has periodically attempted to scan for and anticipate new scientific, technology, and policy developments, these efforts have not been systematic and sustained. The establishment of deliberate and systematic processes for anticipating human health and ecosystem challenges and new scientific and technical opportunities would allow EPA to stay at the leading edge of emerging science (p. 200).

Recommendation: The committee recommends that EPA engage in a deliberate and systematic "scanning" capability involving staff from ORD, other program offices, and the regions. Such a dedicated and sustained "futures network" (as EPA called groups with a similar function in the past), with time and modest resources, would be able to interact with other federal agencies, academe, and industry to identify emerging issues and bring the newest scientific approaches into EPA (p. 200).

Finding: EPA has recognized that innovation in environmental science, technology, and regulatory strategies will be essential if it is to continue to perform its mission in a robust and cost-effective manner. However, to date, the agency's approach has been modest in scale and insufficiently systematic (p. 202).

Recommendation: The committee recommends that EPA develop a more systematic strategy to support innovation in science, technology, and practice (p. 202).

Finding: Environmental problems are increasingly interconnected. EPA can no longer address just one environmental hazard at a time without considering how that problem interacts with, is influenced by, and influences other aspects of the environment (p. 189).

Recommendation: The committee recommends that EPA substantially enhance the integration of systems thinking into its work and enhance its capacity to apply systems thinking to all aspects of how it approaches complex decisions (p. 189).

Finding: It is difficult to understand the overall state of the environment unless one knows what it has been in the past and how it is changing over time. Typically this can only be achieved by examining high-quality time series of key indicators of environmental quality and performance. Currently at EPA, there are few long-term monitoring programs, let alone programs that are systematic and rigorous (p. 201).

Recommendation: The committee recommends that EPA invest substantial effort to generate broader, deeper, and sustained support for long-term monitoring of key indicators of environmental quality and performance (p. 201).

Finding: Research on environmental issues is not confined to EPA. In the United States, it is spread across a number of federal agencies, national laboratories, and universities and other public-sector and private-sector facilities. There are also strong programs of environmental research in the public and private sectors in many other nations (p. 198).

Recommendation: The committee recommends that EPA improve its ability to track systematically, to influence, and in some cases to engage in collaboration with research being done by others in the United States and internationally (p. 198).

Finding: Expertise in traditional scientific disciplines—including but not limited to statistics, chemistry, economics, environmental engineering, ecology, toxicology, epidemiology, exposure science, and risk assessment—are essential for addressing the challenges of today and the future. The case of statistics is one example where the agency is facing significant retirements and needs to have, if anything, enhanced expertise. EPA is currently attuned to these needs, but staffing high-quality scientists in these areas of expertise who can embrace problems by drawing from information across disciplines will require continued attention if EPA is to maintain its leadership role in environmental science and technology (p.195).

Recommendation: EPA should continue to cultivate a scientific workforce across the agency (including ORD, program offices, and regions) that can take on transdisciplinary challenges (p. 195).

Finding: EPA's economic, social, behavioral, and decision science staff consists almost entirely of economists. The agency is without strong expertise in social, behavioral, and decision sciences, though it does support some research in these areas through outside grants, collaborations, and procurement (p. 196).

Recommendation: The committee recommends that EPA add staff who have training in behavioral and decision sciences and find ways to enhance the existing staff capabilities in these fields (p. 196).

Finding: The need for improvement in the oversight, coordination, and management of agency-wide science has been documented in studies by the National Research Council, The Government Accountability Office, and the agency's own SAB as a serious shortcoming and it remains an obstacle at EPA. The committee's own analysis of challenges and opportunities for the agency indicates that the need for integration of systems thinking and the need for enhanced leadership at all levels is even stronger than it has been in the past (p. 192).

Recommendation: The committee recommends that the EPA administrator continue to identify ways to substantially enhance the responsibilities of a person in an agency-wide science leadership position. That person should hold a senior position, which could be that of a deputy administrator for science, a chief scientist, or possibly a substantially strengthened version of the current science advisor position. He or she should have sufficient authority and staff resources to improve the integration and coordination of science across the agency. If this enhanced leadership position is to be successful, strengthened leadership is needed throughout the agency and the improved use of science at EPA will need to be carried out by staff at all levels. The committee specifically recommends that the person in this position and his or her staff create, implement, and periodically update an integrated, agency-wide multiyear plan for science, its use, and associated research needs (pp. 192-193).

Recommendation: Strengthening its scientific capacity. This can be accomplished by continuing to cultivate knowledge and expertise within the agency generally, by hiring more behavioral and decision scientists, and by drawing on scientific research and expertise from outside the agency (p. 13).

Finding: If EPA is to provide scientific leadership and high-quality science based regulation in the coming decades, it will need adequate resources to do so. Some of the committee's recommendations, if followed, will allow EPA to address its scientific needs with greater efficiency. But the agency cannot continue to provide leadership, pursue many new needs and opportunities, and lay the foundation for ensuring future health and environmental safety unless the long term budgetary trend is reversed (p. 203).

Recommendation: The committee recommends EPA create a process to set priorities for improving the quality of its scientific endeavors over the coming decades. This process should recognize the inevitably limited resources while clearly articulating the level of resources required for the agency to continue to ensure the future health and safety of humans and ecosystems (p. 203).

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Appendix E

Summary of EPA Personnel by Laboratory Type for 2013[1]

[1]EPA (U.S. Environmental Protection Agency). 2014. Summary of Personnel by Lab Type. Materials submitted to the committee on March 6 and 27, 2014.

Program Laboratories

Program Laboratories	**Location**	**# of Federal Personnel**	**% of Total Federal Lab Personnel**	**# of Non-Federal Personnel**	**% of Total Non-Federal Lab Personnel**
Office of Air and Radiation (OAR)					
National Air and Radiation Environmental Lab	Montgomery, AL	39		15	
Radiation and Indoor Environments Lab	Las Vegas, NV	7		1	
National Vehicle and Fuel Emissions Lab	Ann Arbor, MI	112		73	
Office of Chemical Safety and Pollution Prevention (OCSPP)					
Analytical Chemistry and Microbiology Lab	Ft. Meade, MD	22		6	
Environmental Chemistry Lab	Bay St. Louis, MS	8		1	
Office of Enforcement and Compliance Assurance (OECA)					
National Enforcement Investigations Center	Lakewood, CO	102		12	
Office of Water (OW)					
Drinking Water Lab	Cincinnati, OH	32		11	
Office of Solid Waste and Emergency Response (OSWER)					
Emergency Response Center	Edison, NJ	0		7	
Total- *Program Labs*		**322**	**71.9%**	**126**	**28.1%**

Regional Office Labs

Regional Laboratories	Location	# of Federal Personnel	% of Total Federal Lab Personnel	# of Non-Federal Personnel	% of Total Non-Federal Lab Personnel
Region 1- New England Regional Lab	Chelmsford, MA	59		18	
Region 2- Division of Environmental Science and Assessment	Edison, NJ	72		46	
Region 3- Environmental Science Center	Ft. Meade, MD	46		50	
Region 3- Freshwater Biology Lab	Wheeling, WV	23		4	
Region 4- Analytical Support Branch	Athens, GA	97		20	
Region 5- Central Regional Lab	Chicago, IL	23		19	
Region 6- Environmental Science Branch	Houston, TX	46		13	
Region 7- Regional Science and Technology Center	Kansas City, KS	60		12	
Region 8- Region 8 Lab	Golden, CO	18		24	
Region 9- Region 9 Lab	Richmond, CA	13		24	
Region 10- Manchester Environmental Lab	Port Orchard, WA	23		49	
Total- ***Regional Labs***		**480**	**63.2%**	**279**	**36.8%**

ORD Labs

Office of Research and Development Laboratories	Location	# of Federal Personnel	% of Total Federal Lab Personnel	# of Non-Federal Personnel	% of Total Non-Federal Personnel
National Health and Environmental Effects Research Laboratory (NHEERL)					
Gulf Ecology Division	Gulf Breeze, FL	63		50	
Mid-Continent Ecology Division	Grosse Ille, MI	5		7	
Mid-Continent Ecology Division	Duluth, MN	82		78	
Western Ecology Division	Corvalis, OR	55		65	
Western Ecology Division	Newport, OR	16		7	
Environmental Public Health Division	Chapel Hill, NC	46		28	
Atlantic Ecology Division	Narragansett, RI	71		45	
National Risk Management Research Laboratory (NRML)					
Ground Water Ecosystems Restoration Division	Ada, OK	51		70	
Water Supply and Water Resources Division	Edison, NJ	7		4	
National Exposure Research Laboratory (NERL)					
Ecological Exposure Research Division	Las Vegas, NV	51		45	
Ecosystems Research Division	Athens, GA	56		57	
National Centers, Research Triangle Park					
Immediate Office of the Assistant Administrator	Durham, NC	17		7	
National Center for Computational Toxicology (NCCT)	Durham, NC	18		27	
National Center for Environmental Assessment (NCEA)	Durham, NC	47		21	
National Exposure Research Lab (NERL) personnel	Durham, NC	177		80	
National Health and Environmental Effects Research Laboratory (NHEERL)	Durham, NC	212		80	
National Homeland Security Research Center (NHSRC)	Durham, NC	11		5	

National Risk Management Research Laboratory (NRMRL) personnel	Durham, NC	58		58	
Office of Administrative and Research Support (OARS)/ Office of Science Information Management (OSIM)	Durham, NC	54		27	
National Centers, Cincinnati OH					
Immediate Office of the Assistant Administrator	Cincinnati, OH	19		1	
National Center for Environmental Assessment (NCEA)	Cincinnati, OH	12		19	
National Exposure Research Lab (NERL) personnel	Cincinnati, OH	73		32	
National Homeland Security Research Center (NHSRC)	Cincinnati, OH	28		11	
National Risk Management Research Laboratory (NRMRL) personnel	Cincinnati, OH	193		127	
Office of Administrative and Research Support (OARS)/ Office of Science Information Management (OSIM)	Cincinnati, OH	37		13	
Total- *Research Labs*		**1,459**	**60.2%**	**964**	**39.8%**
GRAND TOTAL		**2,261**	**62.3%**	**1,369**	**37.7%**