Best Practices in Assessment of Research and Development Organizations: Summary of a Workshop

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Best Practices in Assessment of Research and Development Organizations—Summary of a Workshop

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Laboratory Assessments Board

Division on Engineering and Physical Sciences

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Acknowledgment of Reviewers

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

Ross B. Corotis, University of Colorado at Boulder,
Mark E. Eberhart, Colorado School of Mines,
Katharine G. Frase, IBM Corporation,
Tonya L. Kuhl, University of California, Davis, and
John W. Lyons, National Defense University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse views presented at the workshop, and they did not see the final draft of the workshop summary before its release. The review of this summary was overseen by David E. Crow, University of Connecticut. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the author and the institution.

Contents

1

Introduction

The National Institute of Standards and Technology (NIST)—recognizing that information and insights gained through continual examination of practices for organizational assessment are useful for decision makers at organizations across the federal, industrial, academic, and national laboratory sectors—recently requested that the National Research Council (NRC) organize a panel to review best practices in assessment of research and development (R&D) organizations.[1] In response, the NRC established the Panel for Review of Best Practices in Assessment of Research and Development Organizations. The panel was charged to consider means of assessing the following, in a manner that satisfies the requirements of NIST to perform effective assessments but also identifies assessment methods that can be applied selectively to other R&D organizations:

- Technical merit and quality of the science and engineering work
- The adequacy of the resources available to support high-quality work
- The effectiveness of the agency's delivery of the services and products required to fulfill its goals and mission and to address the needs of its customers
- The degree to which the agency's current and planned R&D portfolio supports its mission
- The elements of technical management that affect the quality of the work
- The extent to which the agency is accomplishing the impact it intends
- The agency's flexibility to respond to changing economic, political, social, and technological contexts

As one means of data gathering, among others that the panel is performing toward development of a final report of its findings, the panel organized a planning committee for a workshop on best practices in assessment of R&D organizations. The workshop was conducted at the Keck Center of the National Academies in Washington, D.C., on March 19, 2012.

[1] Appendixes A, B, C, and D in this report present, respectively, the agenda of the workshop, a list of the attendees, and biographical sketches for the planning committee and panel members and for those who made presentations at the workshop.

This report has been prepared by the workshop rapporteur as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning and convening the workshop. The views contained in the report are those of individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, or the National Research Council.

The workshop addressed the broad subject of best practices in assessment, with a focus on elucidating two key aspects of organizational assessment: (1) evaluation of the technical quality of an organization's R&D work and (2) assessment of the effectiveness of the organization in addressing its mission and the needs of customers and stakeholders. Appreciating the importance of individual differences across organizations, the committee set as a desideratum for the workshop the identification of a variety of assessment questions and methods for addressing them, which might then constitute a tool kit of assessment questions and methods that could be tailored for application by individual organizations.

During the morning session of the workshop, six distinguished individuals each provided a presentation. The collective expertise of the presenters, listed below in the order of their presentations, spans the management of R&D activities within congressional, federal, industrial, and academic environments (see their biographical sketches in Appendix D). The audience of workshop participants consisted of approximately 100 representatives of organizations within those sectors (see Appendix B for the list of participants).

- James H. Turner, Counsel and Director of Energy Programs at the Association of Public and Land-grant Universities, and former chief counsel to the U.S. House of Representatives Committee on Science and Technology;
- John C. Sommerer, Head, Space Sector, and Johns Hopkins University Gilman Scholar, Johns Hopkins University Applied Physics Laboratory;
- J. Stephen Rottler, Chief Technology Officer and Vice President for Science and Technology, Sandia National Laboratories;
- William F. Banholzer, Executive Vice President and Chief Technology Officer, The Dow Chemical Company;
- Roy Levin, Distinguished Engineer and Managing Director, Microsoft Research, Silicon Valley; and
- Gilbert F. Decker, Consultant, former Assistant Secretary of the Army for Research, Development and Acquisition.

During the afternoon session of the workshop, attendees formed seven separate groups, six of which included one of the morning presenters. Each group discussed best practices in assessment, with attendees sharing their insights and experiences. At the conclusion of the workshop, a rapporteur from each of the groups provided a brief oral summary of the group's discussion.

Chapters 2 and 3 of this report provide, respectively, summaries of the morning and afternoon sessions of the workshop. In Chapter 2, the workshop rapporteur, James P.

McGee, director of the NRC's Laboratory Assessments Board, summarizes each of the six presenters' talks. In Chapter 3, the questions raised by the discussion groups are organized according to elements of the statement of task of the Panel for Review of Best Practices in Assessment of Research and Development Organizations.

2

Summary of Presentations

The following summaries of the presentations by James H. Turner, John C. Sommerer, J. Stephen Rottler, William F. Banholzer, Roy Levin, and Gilbert F. Decker were prepared by the workshop rapporteur, James P. McGee. Except where noted, comments in the summaries are attributable to the speakers.

Presentation by James H. Turner: Impact of Assessments and Merit Reviews on Stakeholders

Introducing the first part of his presentation, James Turner referred the audience to a report that he had prepared for the U.S. Department of Energy (DOE) and that had been published by the Association of Public and Land-grant Universities—*Best Practices in Merit Review: A Report to the U.S. Department of Energy, December 2010.*[1] For purposes of examining its energy portfolio, the DOE had asked how peer review should be performed at the department, and the topic was addressed at a DOE-sponsored workshop, held in January 2010, that is addressed in *Best Practices in Merit Review.*

Turner emphasized that assessments should include measurement against goals and intentions. Basic research and applied research are distinct. The goal of applied research is to get a task done on time and within budget. The goal of basic research is to develop science to the cutting edge and beyond.

Speakers at the January 2010 DOE workshop from industry and venture-capital research organizations showed commonality in various areas. For example, they did not want to spend time and funds evaluating proposals. Their emphasis was on their desire to secure the best team rather than worry about the details of proposals. They considered past research the best indicator of future success. They suggested that managers must be hands-on and aware that time is the enemy (the maximal time line for achieving commercialization is generally 4 years for industry and venture-capital initiatives). They suggested that if no progress is evident after a year or two, the work should be stopped and efforts directed elsewhere. They believed that every 3 to 6 months, work plans and progress should be assessed, that reviewers should be changed after 2 to 3 years, and that reviewer expertise should be based on current assessment needs. They said that the goal of the R&D efforts is to move to the marketplace. It was noted that the Department of Defense (DOD) has its "marketplace" as well, and that the DOD desires to streamline its procurement processes.

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[1] James Turner, *Best Practices in Merit Review: A Report to the U.S. Department of Energy, December 2010*, Washington, D.C.: Association of Public and Land-grant Universities. Available at http://www.aplu.org/document.doc?id=2948. Accessed August 21, 2012.

Speakers at the January 2010 DOE workshop from organizations and agencies with a focus on basic research also shared common opinions, but their opinions differed from the opinions of those at that workshop who expressed a focus on applied research. Those who emphasized basic research considered it important to examine every proposal and proposer and to ask whether each team had the expertise, equipment, and facilities to succeed. They agreed that there is a need for competent researchers, but they also saw a need to fund new researchers and ideas. They contended that diversity of peer reviewers helps to enhance recognition of innovative proposals.

Participants at the DOE workshop highlighted a need to collectively evaluate the importance both of advancing the state of the art in basic research and of performing applied research.

For the second part of his presentation, Turner examined three stakeholder groups that he believes should be considered by government laboratories when assessing the satisfaction of stakeholder needs: the U.S. Congress, the Executive Branch, and the public.

The Congress is a trailing indicator, rather than a leading indicator. It is difficult for Congress to influence without achieving a consensus. Congress reports to its members' constituents, the voting public. Responding to congressional leadership is important for the members of Congress, as is being mindful of reelection. Congress is a legal society in the sense that approximately half of the U.S. Senate and a third of the members of the U.S. House of Representatives are lawyers. For the Congress, it is axiomatic that a good anecdote is the coin of the realm.

So where does assessment evidence fit in? It is one step removed from the Congress. Congressional staff review assessment reports and have a key role in drafting bills. The congressional authorizing committee chair influences the Appropriations Committee chair. These are ultimate targets and prime readers of assessment reports. In general, congressional attention is thinly spread.

Other targets of assessment reports are the Executive Branch, support agencies (e.g., the Congressional Research Service and the Government Accountability Office), and think tanks (e.g., the National Research Council and the Cato Institute). Reports from those institutions make a great impact. The National Research Council and other think tanks have good reputations with the Congress.

The Executive Branch usually has its way during appropriations, and so influencing the Executive Branch is important. The most important stakeholder, though, is the public.

Presentation by John Sommerer: Assessing R&D Organizations—Perspectives on a Venn Diagram

In his opening remarks, John Sommerer noted that organizations are motivated by the desire to innovate. The context within which an R&D organization exists is everything. It is not feasible to develop an assessment approach that will be applicable across all organizations—a tool kit is needed. When assessments go badly, it is because an approach is applied without regard to context. For example, academic metrics can be inappropriate for the assessment of stakeholder satisfaction.

The three main influences on Sommerer's thinking in this regard have been Vannevar Bush,[2] Terence Kealey,[3] and Donald Stokes.[4] Vannevar Bush proposed the linear model of innovation that is now codified within the DOD (as 6.1, 6.2, etc., levels of R&D maturity). That approach, which assumes a linear transition from basic research to applied research, to development, and production, is fundamentally wrong. Rarely does innovation operate according to a linear model.

Terence Kealey updated the linear model to include on-ramps, off-ramps, and feedback loops. He assumed that old science informs new science and old technology informs new technology and that only infrequently do they interact, but when they do, frequently serendipitously, significant results are produced. Kealey was hostile to the concept of government investment in R&D. This is a well-documented perspective—the view that government investment is lacking in appropriate context and motivation (it is a trailing rather than a leading indicator), and the frequent result is waste. Kealey's perspective is that an R&D organization exists as a modus vivendi between stakeholders of the organization and its researchers, and that one cannot get people capable of embracing and understanding the cutting edge of literature to capture value for the parent organization unless one gives them money to play with. Sommerer noted that one cannot expect a staff of nonpractitioners (those who are not directly and intimately involved with the R&D activities) to cull the literature for the purpose of identifying value for an organization, because they do not have the appropriate insights. Even in a private-investment context, an R&D organization is a way of having a captive populace to extract value from cutting-edge activities.

Donald Stokes identified an innovation web and emphasized the need to address very hard problems.

Sommerer emphasized that an R&D organization is successful if and only if there are three components in synergistic support: alignment, vision, and people. The interaction of these components can be illustrated by a Venn diagram in which the three components are represented as overlapping sets.

The alignment component is addressed by asking the following questions, and any assessment, even of technical quality, needs this context: Does the parent stakeholder have a strategy articulated with clear milestones so that it can be internalized by the organization? Does the organization have a supportive strategy? Is there a clearly articulated vision of what the parent/organization is trying to achieve according to some

[2] Vannevar Bush, *The Endless Frontier*, Washington, D.C.: U.S. Government Printing Office, 1945. Available at http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm. Accessed August 23, 2012.
[3] Terence Kealey, *The Economic Laws of Scientific Research*, New York, N.Y., Palgrave MacMillan, 1996.
[4] Donald E. Stokes, *Pasteur's Quadrant*, Washington, D.C.: Brookings Institution Press, 1997.

milestones? Are all of these elements in synchrony? Are these strategies mutually supportive and updated? Are they good or bad strategies? Within this alignment, is the organization looking for first-mover advantages or second-mover advantages? What developments does the organization consider important to capture?

The vision component is addressed by asking the following questions: Does the organization know what it wants to become (in 1-, 5-, 10-year frameworks)? What expertise is it trying to achieve? Acknowledging that strategy is about what one is going to do and *not* do, where does the organization choose to be a leader as opposed to being a follower of fast developments? Does the organization have expertise in areas in which it desires to be a leader, and less expertise in areas in which it desires to be a follower? Are the synergies nurtured? Are there exit strategies? Are there realistic stretch goals? Are there sufficient resources? A vision without resources is a hallucination.

The component of people is addressed by the following considerations: Human capital is fundamental. Innovation requires free energy—that is, giving researchers some latitude and discretion in their work. There is no hope for the future of an organization without free energy. Peer reviews, which measure competence, have been well defined, but it is more difficult to measure motivation and external engagement. There is a need for external engagement globally in order to innovate. An assessment of human capital should ask: Are the people in the organization trying to become better?

The intersection of people with alignment is addressed by the following questions: Do the people know the strategy of the organization and its parent? Are there mechanisms by which the people can contribute to the strategy? Can they interact with the organization's customers? Are the leaders administrators or role models? What are their credentials and qualifications? Do they have a strategy to support the people of the organization? Does the organization assess and mentor the people? Does the organization have the will to release people who should not be there? Does the organization have a strategy and the resources for engagement with the external world and for encouraging such engagement? Is innovation welcome, supported, protected? External engagement must be focused on the broad global community.

The intersection of vision with alignment is addressed by the following questions: Is there updating of the vision in response to changing external factors? Is there a process of self-assessment? Is there a list of lessons learned, and are they really learned, not just recorded? Is the self-assessment diligent, and does it have integrity? Is the assessment updated in acknowledgment of new strategies? There is need for both bottom-up and top-down assessment.

The intersection of people with vision is addressed by the following questions: Do the people within the organization know the vision? Can the people contribute to the vision? Does the R&D organization have a strategy and appropriate resources for engagement with the larger technical community, the commercial sector, and the global community? Is innovation welcomed, supported, and protected?

The intersection of vision, people, and alignment is addressed by an examination of the organization's agility, flexibility, and adaptability in the face of changing pressures, budgets, and external contexts. This intersection needs to be consciously worked by staff and leadership, and it must be internalized.

There are potential cautions for external reviewers: Even robust review processes can be susceptible to inappropriate coaching. Any organization being assessed by an external group has a stake in the assessment. External assessment groups must be careful not to be used. An organization's suggestion that the assessment be restricted to a "narrow lane" without the reviewers' understanding the context of the organization and of the assessment is a warning sign of an attempt to influence the assessment. Given the freedom to do so, external reviewers can be very helpful in identifying suggestions for addressing the context questions mentioned here.

Presentation by J. Stephen Rottler: Assessing Sandia Research

J. Stephen Rottler emphasized that Sandia National Laboratories has undergone a continuous evolution of assessment of quality, relevance, and impact, with quantitative assessment evolving into qualitative assessment that is informed by data.

Organizations are complex systems, composed of interconnected parts. The properties of the whole organization are not necessarily perceived by looking at individual parts. Systems behave in nonlinear ways that can be difficult to predict. Assessors must probe, watch behavior, probe, watch behavior, iteratively, being mindful that their assessment impacts behaviors. Over time, there has been a need to shift from quantitative to qualitative assessment informed by data.

According to Jon Gertner's book titled *The Idea Factory: Bell Labs and the Great Age of American Innovation*,[5] the characteristics of Bell Laboratories, identified in that book, have been deliberately nurtured at Sandia. These characteristics, which cannot be reduced to simple rules, must be applied dynamically. They are as follows:

- A critical mass of talented doers and thinkers;
- An environment that encourages interaction, and an open-door policy under which experts are expected to participate in the everyday mix of work and to mentor junior staff;
- Multidiscipline research teams who understand that the aim of the organization is to transform knowledge into new things;
- Freedom (and time) to pursue solutions thought to be essential; and
- Rich knowledge exchange between the creators and the users.

[5] Jon Gertner, *Bell Labs and the Great Age of American Innovation*, London: Penguin Press, 2012.

Organizations that traditionally have been stovepiped are increasingly evolving strategies and funding approaches that acknowledge the importance of multidisciplinary research organizations.

Sandia performs assessment in order to continue to improve the performance of the laboratory as an organization. Sandia addresses serious and high-consequence security challenges faced by the nation. It must deliver to requirements today and in the long term, and position itself to operate and deliver according to long-term requirements. Sandia focuses on the assurance of error prevention—developing and exhibiting behaviors so that errors are less likely to occur. Peer-review and external advisory boards examine pathways to error so that the probability of success can be maximized.

There are three assessment categories: (1) Self-assessments are intended to be objective but are inherently limited. All successful organizations have mature self-assessments that are objective and that promote responsive behaviors. (2) Independent assessments conducted through external peer reviews and visiting committees (external advisory boards) are used to examine quality, relevance, impact, and responsiveness to customers. (3) Benchmarking compares an organization to other organizations and is accomplished by formal assessments (by visiting other organizations) and less formal interactions as well.

Self-assessment at Sandia has become increasingly more formal and disciplined. Quarterly assessments present opportunities for leaders to examine with their teams whether their expectations about quality, relevance, and impact are being met. These assessments are performed at all levels of management.

Independent assessments are performed through a research advisory board that meets twice a year. The board is composed of senior individuals drawn from across academia and the public sector. The board is used in a broad sense to assess technical quality, using external measures and comparison against other organizations. The assessment examines whether Sandia is meeting the criteria of its roles as fast follower or first researcher. It also examines the health of the research environment and connections with internal and external customers. It elucidates what is either working or getting in the way in terms of innovation. The board also meets with customers of the organization and examines the impacts of prior investments. It assesses whether investments have enabled the laboratory to continue fruitful work or to initiate new work.

Laboratory Directed Research and Development (LDRD) funds are an important element of Sandia. Sandia's director is permitted to decide how the LDRD funds are allocated across projects consistent with Sandia's mission. The National Nuclear Security Administration (NNSA) provides oversight for this program, which captures principal-investigator-generated ideas within the management context. The program includes 5 or 6 grand challenge projects; each of these larger projects has an assigned external advisory board. Historically, these larger projects have transitioned successfully to have impact within Sandia or have achieved follow-on external funding—these impacts have been achieved with the help of the external advisory boards.

Assessments have traditionally been performed according to a balanced scorecard that guides the selection of data to support assessment decisions. Metrics are defined to assess three areas of measurement: value to customers, outputs, and inputs. Within each area, metrics are defined to support the assessment of what the organization is doing and how it is doing it. To assess value to customers, the value and impact in terms of leadership, stewardship, and mission satisfaction are addressed by examining measures of the effectiveness of strategic partnerships with industry and technical collaborators. To assess outputs, the excellence of scientific and technical advances is addressed within the context of management excellence, which involves measuring elements of the work environment and management assurance. To assess inputs, the capabilities of staff, technology infrastructure, and facilities are addressed by examining the science, technology, and engineering strategy through measurements of parameters indicative of the portfolio and the technical planning process.

The evolving assessment processes at Sandia increasingly include an examination of qualitative factors informed by the quantitative data. The following elements are assessed: clarity, completeness, and alignment of the research strategy; alignment of the research with the organization's missions; quality and innovation of the research; vitality of the organization's scientists and engineers; and long- and short-term impacts of the research with respect to the organization's missions and to advancing the frontiers of science and engineering.

In summary, organizations and their assessors should be clear about the purposes of the assessment and its context; carefully decide what data to collect and what the assessment framework is; and link the assessment to the organization's concept of what makes a great organization. Management is a qualitative sport, not a quantitative sport, but management in the absence of data is vacuous. The role of a leader in an R&D organization is to clearly express expectations to coworkers, to assess constantly whether those expectations are being met, and to take action to correct cases in which the expectations are not being met.

Presentation by William F. Banholzer:
An Industrial Perspective

William Banholzer introduced his presentation by noting that industry does not have a right to do research—research is a privilege earned by creating value. Value means that industry can commercialize something and that someone will pay for what industry has done. Therefore, for industry, three questions must be addressed: What do people want? What will people pay for? What can they afford?

Industrial organizations must convert research efforts into products that people want, will pay for, and can afford. Industry always has this compass: return on investment (ROI) of research expense versus gain. By examining impact to society (i.e., will society purchase the product?) one can define benefit beyond such metrics as scientific publications.

Also, there are multiple stakeholders, including stockholders, employees, government, and suppliers. Each context—industry, academia, government—has different stakeholders, whose interests must be balanced and addressed. Sometimes these different interests are not aligned. Customers are those who pay for a product; stakeholders are those who have a vested interest in an organization. For industry, customers and shareholders are those to whom the organization sells and is responsible; stakeholders may include the government, community, employees, and suppliers. For universities, customers are the students, and stakeholders are parents, the community, the faculty, and society at large. For the national laboratories, customers are the sponsoring government department and society, and stakeholders are taxpayers, the community, employees, and companies.

Assessment practices must show recognition of the importance of time frame. The time frame for technology development is getting shorter and shorter. It is increasingly necessary to invest faster, and this has implications for the metrics used for assessment. The economy has also cycled—because almost all products involve chemistry, the chemical industry profits have followed the economic trends. The typical 7-year cycles are driving the need for faster research; cycles are getting shorter.

Commercial launch represents enormous investment. “Materiality” refers to the point at which the cumulative investment is matched by cumulative sales. Sales do not equal profit, and so the break-even point is even farther out. Materiality points are up to 15 years out, and the cash-flow-positive point can be 25 to 30 years. In the meantime, investors are asking, “What have you done for me this quarter?” The message is that R&D is a long-term endeavor, and evaluations must consider the time frame. However, an organization cannot simply say, “Trust me for the long term.” Competitive analysis (pointing to how much competitors are spending) does not convince management. Not all technologies have same time frames; for some areas (e.g., energy) one has to think in decades.

Great science does not necessarily convert into great business. Pragmatically, science is a necessary but not sufficient condition. Organizations must be wary of claims by poor science and fads. Fads have had a perturbing effect on our pragmatic research.

What gets measured gets done. Measurements in industry are usually historical. R&D as a percent of sales, number of new product sales, and number of patents are woefully inadequate to define success of an industrial organization. The assumption that spending a lot yields great results is a flawed assumption. Better metrics are:

- New product sales/R&D investment: a measure of productivity;
- Margin on new products: new products are accountable for expanded earnings;
- Patent-advantaged sales: reveals whether patents are protecting sales.

These metrics apply to industry, but they may not apply to national laboratories. An organization needs to define its customers and its criteria for success. Patents and publications do not indicate impact. The question to ask is, What would happen if you were not there? This question is more complicated when considering the long-term time frame.

National laboratories should measure impact and some form of ROI. Successes can be communicated through anecdotes, but past history does not prove future success. It is critically important to look at an organization's total portfolio and to examine how well the organization is spending the whole portfolio, not just the best portion of it. If an organization wants to succeed, it must play to succeed. Failures should be appreciated if they represent reasonable attempts at addressing challenges. National laboratories must consider their R&D by comparison with centers of excellence, and the national laboratories need more exposure to industry.

Assessments should consider as key the question, Who are the customers and stakeholders, and how do they define success?"

Presentation by Roy Levin:
Managing Innovation at Microsoft Research

Roy Levin emphasized that context is everything and that Microsoft Research (MSR) is in the business of innovation. MSR has laboratories in six locations around the world. Research at Microsoft is not part of the product organization. Focusing on research, MSR is funded as a corporate function. The MSR mission is to perform basic research and to advance the state of the art—which does bring advances quickly into products and services. The management challenge is to transition research into products and services. MSR contributions to Microsoft products are direct (by providing products) and indirect (by building software tools that enable product development).

The role of a research organization overall is to address the long term. MSR exists to look out for the company's future. The rationale for the existence of a research organization is to provide the capacity to deal quickly with the unknown and unexpected. Disruptive technologies, new competitors, and new business models can occur suddenly and must be responded to. An example was Microsoft's ability, supported by its forward-looking research, to respond effectively to Bill Gates's exhortation to attend to the evolving Internet.

There are several norms in research at MSR. It conducts a broad spectrum of research in computer science and other fields, including social sciences. Research is bottom-up. Researchers, not managers, develop the projects and programs. The job of the research manager is to hire the best people and support them. Research is collaborative, both within the organization and with external collaborators such as product groups and academia.

MSR maintains a flat management structure as much as possible. This affects the size of the organization—the span of control at MSR is 70 people, so the management leader can interact individually with each staff member. Larger organizations can adopt this approach by breaking the research organization into smaller groups.

Work at MSR is "open"—most work is published. This is key for basic research and needed for effective collaborations. A research organization cannot reap from the community without participating in it. Software is based on intellectual property. MSR seeks patent protection for defensive purposes.

MSR is modeled after academia, with academic principles applied to this corporate computer science department, which is larger than that found in academic institutions. MSR seeks to publish at the right time, with emphasis on quality of publication, rather than to emphasize quantity of publications.

MSR applies formal assessment mechanisms. Mechanisms include peer-reviewed publication: how work is reviewed by external peers and whether it is published in the best venues (journals and conferences). External awards and participation on program committees and editorial boards are considered as vehicles that create publications and show leadership in the field. A corporate annual review is also conducted; its mechanisms are designed to serve the larger corporation and are not focused on research. These annual reviews include feedback from peers within MSR, the rest of Microsoft, and externally, generally with attribution of the feedback comments. Formal "stack ranking" that compares researchers at similar career levels is performed, although it is sometimes tantamount to comparing trees with rocks—corporate interests generally focus on shorter terms than do those of researchers. Researchers need to have faith that the corporation will support them even though their work does not often map to the corporate evaluation cycles. The assessment process must be tweaked by the manager to consider the expected time frame for each researcher. The assessments also include formal one-on-one meetings of staff with the MSR manager.

Less formal assessment mechanisms are also applied. Mentors provide feedback unencumbered by financial considerations. Mentors are internal, more senior researchers who provide career development guidance to mentees. Mentors draft the annual performance review, which is reviewed by the organization's manager. Weekly all-hands meetings include technical talks; everyone provides a technical talk once per year. These talks are highly interactive, with discussion of innovative ideas preferred.

The hiring process is also collaborative, and it is considered the most important thing done in a research organization. Across-the-lab interviewing is conducted to cover all of the relevant technical areas; it assesses the breadth and depth of a candidate's interests and capabilities. Committees-of-the-whole involve the entire MSR organization in hiring discussions. Management-by-walking-around is a key element of informal assessment, which should not be confined to annual review.

MSR evaluates what gets done, how it gets done, and when it gets done. In assessing "what gets done," MSR looks at whether individuals and teams are advancing the field (e.g., through publication and professional service); helping Microsoft (e.g., through technology transfer, consulting, or spending time embedded within a product organization); and ensuring the future (e.g., through strategic engagement with product divisions and other parts of the corporation that consider strategy).

In assessing “how it gets done,” MSR evaluates collaboration (with the understanding that the best research usually involves collaboration); individual initiative; and success at mentoring others. In assessing “when it gets done,” MSR evaluates time to expected payoff and appropriate milestones. MSR recognizes that most deadlines are self-imposed but need some sense of when payoff can be expected. Ultimately management must decide whether to continue or stop a project or program.

In aggregate, MSR assesses the impact of research on the field of computing and on Microsoft Corporation.

Presentation by Gilbert F. Decker: Concepts for Assessment of R&D Organizations

Gilbert Decker introduced his presentation by noting that industry and government, and to an extent academia, quite often use the term “research and development,” although in reality these are two somewhat different but related functions. It is constructive to discuss research and development and to show the differences in the assessment of each. The *New Oxford American Dictionary* defines research as both a noun and a verb. The noun is defined as “the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.” Then, of course, the verb is defined as “the act of conducting research.” The term “development” is best defined here as “the creation of a new or refined product or idea.” Said another way, research is usually based on a hypothesis and on the design of an experiment or analyses to confirm or disprove the hypothesis; development is the creation of a product.

Having defined terms, it is useful to discuss the assessment of development programs, followed by a discussion of the assessment of research programs and then a comparison of the two. Usually the objective of a development program is to produce a product that has applications and can be sold in the market and/or used by mission organizations, such as the military, to accomplish needed functions. The beginning of a development program, to be successful, requires fairly rigorous descriptions of the functions that the product must perform and specifications that drive the design. Consequently, the assessment of the quality and success of a development program is based on some definable metrics. Further, processes of managing the development program also need to be well defined, although they are not always well executed. One very key factor in the decision to begin a development program is the maturity of the technology. If the program is not based on known facts and conclusions established from proven research results, it is clearly unwise to pursue it. If one believes in the program, but it is not ready, it is best to recycle it back into applied research. Additionally, a development program usually has fairly rigorous cost estimates to which it tries to adhere.

So, the assessment of a development program has fairly straightforward metrics, based primarily on two parameters: how well the program functions compared to its intended functions and specifications, and how well it adheres to its cost estimates. Both of these assessment criteria can be measured by means of a well-designed test program.

Research is often described in two categories: basic research and applied research. A descriptive definition of "basic research" is that which is carried out to increase understanding of fundamental principles. It is not intended to yield immediate commercial benefits; basic research can be thought of as arising out of curiosity. However, in the long term, it is the basis for many commercial products and for applied research. Thus, basic research is a quest for knowledge and understanding. A descriptive definition of "applied research" is that which is designed to solve actual problems, rather than to acquire new knowledge or theory for its own sake. The objective of applied research is to define new concepts that are based on knowledge, theory, and understanding from basic research.

There is no sharp dividing line between basic and applied research. Both categories are often carried out in research organizations, such as at research universities and in government laboratories. Often, the results of basic research become evident, and the research team may morph into an applied research program.

There are two dimensions in assessing research and development activities: quality and relevance. Assessing quality is the focus of evaluating the technical merit of science and engineering work. The following issues are germane to the consideration of both quality and relevance: the adequacy of the resources available to support high-quality work; the effectiveness of the organization's delivery of the services and products required to fulfill its goals and mission and to address the needs of its customers; the degree to which the organization's current and planned R&D portfolio supports its mission; and the elements of technical management that affect the quality of the work.

As with development programs, metrics are required to assess the quality and relevance of research programs. Such metrics for research programs are not uniformly numerical measurements; or if numerical scoring is desired, the numerical assessment may require that judgments be made by skilled and experienced people, including peers and research managers.

In the case of basic research, relevance should not be weighted as heavily as quality. That is simply because of the definition and goal of basic research: the quest for new knowledge and understanding for its own sake. One should focus on quality of the research organization itself and also on the quality of the individual research programs. Assessments of applied research should address both relevance and quality.

The candidate metrics for assessing the quality and relevance of basic and applied research, presented below, are drawn in large part from two studies: *Managing Air Force*

Basic Research[6] and *Improving Army Basic Research.*[7] Gilbert Decker was a member of the committee that conducted the former study and chaired the committee that conducted the latter study.

Metrics for assessing the technical merit and quality of the science and engineering work include the following:

- *Membership in professional societies*. A high percentage (perhaps at least 75 percent) of the researchers of the organization should be members of professional organizations.
- *Memberships in the National Academies and/or high recognition by professional societies*. A very low percentage would be indicative of overall inadequacy of staff.
- *Number of members of research staff who have been awarded National Medals of Science*. There should certainly be at least two or three who have received this award. This is probably a good indicator of the overall quality of the research staff, the theory being that winners of these medals would not be part of a low-quality research organization.
- *Whether the research organization maintains a database of research projects, findings and results*. This database should also include lists of publications in refereed journals, citations, and awards. It should also include, based on the findings and results, an assessment of lessons learned by the researchers on each project. Lessons learned from failed projects can be as valuable as those learned from successful projects. Such a database could enable an assessment by funding organizations and scientific peer-review committees of the quality of basic research as well as applied research.
- *Percentage of research staff members with doctorates and/or postdoctorate fellowships*. Something greater than 50 percent is the metric for recognized high-quality research organizations.
- *The balance between internally sponsored basic and applied research funding and customer funding that seeks applied research and/or engineering support to address specific problems*. High-quality research organizations have 10 to 15 percent of their total funding in internally generated basic and applied research projects; another 25 to 30 percent is devoted to applied research funded by external organizations looking for concept solutions to problems; the remainder is allocated to scientific and engineering support to advanced development programs. When the internally generated basic and applied research effort falls significantly below 10 percent, the overall quality and stature of the research organization diminish significantly.

The following are management functions: providing the resources available to support high-quality work, effectively delivering the services and products required to

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[6] National Research Council, *Managing Air Force Basic Research*, Washington, D.C.: National Academy Press, 1993.
[7] G. Decker, J. Davis, R.A. Beaudet, S. Dalal, and W.H. Forster, *Improving Army Basic Research: Report of an Expert Panel on the Future of Army Laboratories*, Santa Monica, Calif.: RAND Arroyo Center, 2012.

fulfill the organization's goals and mission and to address the needs of its customers, and maintaining a current and planned R&D portfolio that supports the organization's mission. Generally, managers or directors of research organizations should be scientifically trained personnel with research experience. There are certainly exceptions, but they are few; directors must genuinely understand and believe in basic and applied research. The manager must be capable of assessing and prioritizing research proposals from the research staff and from external funding sources and must also ensure that the aforementioned database is rigorously maintained. The manager must also be the marketing leader in finding research grants for internally generated basic and applied research proposals; must support customers who are seeking solutions to problems using applied research; and must diligently push for balance between internally generated basic and applied research proposals, customer-funded basic research proposals, and customer-funded advanced engineering support. Non-academic organizations (e.g., corporations and government organizations) which include R&D organizations that are productive in both research and engineering are most successful when the R&D director or manager reports to the overall leader of the organization.

The following ideas for assessment processes might be considered:

- The research organization should conduct internal assessments of about 25 percent of basic and applied research projects, randomly selected each year, using the assessment criteria.
- The research organization should have a "blue ribbon" external panel of scientific experts to assess the internally reviewed projects with respect to the assessment criteria. The external review should be compared with internal assessments, using the same criteria.
- The research organization should solicit feedback from external customers who fund projects. The solicitation for feedback should be oriented around customer satisfaction. The feedback survey should be a tailored version of the assessment criteria.
- The research organization should review the research staff composition annually with regard to the quality of staff and mix of staff expertise.

3

Key Questions Identified by Discussion Groups

At the conclusion of the workshop, a rapporteur from each of the six afternoon discussion groups provided an oral summary of the group's discussion. The summary comments are organized below according to elements of the statement of task for the Panel for Review of Best Practices in Assessment of Research and Development Organizations. (The panel's statement of task is presented above on page 1 of this report.) The following summary comments are phrased as a set of questions that might be considered during assessments.

Organizational Context: Does the Organization's Current and Planned Portfolio Align with Its Mission, and Are the Organization's Plans and Strategies Aligned with the Needs of Its Customers and Stakeholders?

In their presentations, John Sommerer, Roy Levin, and J. Stephen Rottler highlighted the importance of recognizing and addressing the context within which a given R&D organization exists. James Turner emphasized that assessments should include measurement against organizational goals and intentions. Sommerer emphasized the importance of a clearly articulated vision of what the parent or organization is trying to achieve according to established milestones. Gilbert Decker emphasized that the following are key management functions: providing the resources available to support high-quality work, effectively delivering the services and products required to fulfill the organization's goals and mission and to address the needs of its customers, and maintaining a current and planned R&D portfolio that supports the organization's mission. William Banholzer noted that an industrial organization must remain mindful of three questions: What do people want? What will people pay for? What can they afford? Banholzer noted that assessments should consider the importance of R&D time frames and should address the question, Who are the customers and stakeholders, and how do they define success? Workshop discussants also identified the following questions:

- Does the assessment reflect understanding of the principle that context is, indeed, fundamentally important, and that the whole organization should be assessed, not only individual programs, projects, units, or people?
- Is the organizational environment created to produce outcomes?
- What is the organization's definition of success?
- What are the appropriate time frames for research and development efforts being assessed?
- Is the assessment in synchrony with changing time frames?
- How is the relationship between the organization and its customers and stakeholders being addressed?
- Does the agency that funds the research have an appreciation for research?
- What is the level of direct interaction with customers?

- Are there mechanisms in place to cut stagnant and unnecessary programs in order to prevent the dilution of the quality of more important programs?
- How should the impact of programs in basic research be assessed?
- How should innovation be assessed?
- How should spin-offs and transitions be measured?
- How are publication citations and patents—measures of the transition of knowledge—assessed?
- Are assessment metrics focused on outcomes as well as on activities?
- Are both historical impact and predictions of future success considered?

How Good Is the Technical Merit and Quality of the Science and Engineering Work?

J. Stephen Rottler emphasized that there has been a need within his organization to shift from quantitative to qualitative assessment informed by data. Workshop discussants identified the following questions:

- Is there external oversight of the assessment, even if the assessment is not being conducted by an external review board?
- Is there a strong internal review to ensure that the product is not trivial before being submitted to external review? Is this applied to publications (especially for scientific publications) as well as to programs?
- To allow for candor without worry about giving offense or meeting with reprisal, especially in small scientific communities, do external reviews include processes to preserve anonymity?
- Are the terms of external review board members appropriate (generally between 3 and 5 years)?
- Does the review team have a balance of expertise and backgrounds?
- Do the review team members have good community reputations?
- Does the chair of the review team show good judgment?
- Has a clear tasking charge been provided for the assessment team?
- Has the audience for assessment reports been identified?
- Have mechanisms for both formal and informal communication of assessment findings been established?
- Is benchmarking included in the assessment as a useful means for assessing process factors—that is, how things are accomplished within the organization?

What Are the Elements of Technical Management That Affect the Quality of the Work?

Each of the six presenters examined elements of technical management that affect the quality of the R&D scientific and technical work. Workshop discussants identified the following questions:

- Does the organization document processes and outputs when metrics are desired? Are the metrics that are gathered appropriate to permitting an examination of the data and trends for making decisions about actions to take?
- How do organizational decision makers perform judgments based on assessment of risk?
- Is a record kept of anecdotes, which often communicate accomplishments better than quantitative metrics such as publications and patents?
- Is the organization's management assessed? Does the assessment ask staff how well management is performing? Are the senior managers technically competent? Does the organization have in place mechanisms to remove pathological managers who will not hire individuals more competent than themselves?

Are Adequate Resources Available to Support High-Quality Work?

John Sommerer noted that a vision without resources is a hallucination. He and Roy Levin emphasized that human capital is a fundamental resource and that innovation requires that researchers be given some latitude and discretion with respect to their projects. Workshop discussants identified the following questions:

- How well does the organization support the education and development of staff?
- How well does the personnel selection and assessment system provide and maintain good performance? Are there any constraints on the system (e.g., constraints imposed within the federal context)?
- Are incentives in place to recognize individuals and teams?
- Are there efforts within the organization to seek external recognition?
- Does the organization promote teamwork? Does management connect with the team to discover talent, through social networking and an open-door policy?
- Does management communicate with junior researchers?
- As a measure of teamwork, are common cross-discipline terminologies used by the staff and the management?
- Do the staff members possess both technical and social skills?
- As a measure of organizational flexibility, how do the initial academic degrees of staff compare with their current work tasks?
- How does the organization inspire stellar performers? Does the organization have a rigorous and transparent process of rewards and acknowledgments in which the staff have confidence and faith?
- Does the organization have mechanisms for moving aside ossified individuals and those who block the performance of others—mechanisms whereby nonperformers can be flushed out?
- Are "wild ducks" (brilliant oddballs) identified and embraced?
- Are rewards other than money available to staff?

- Is there a mentoring system that creates a direct interaction between mentor and mentee in order to enhance productivity?
- If the organization applies a force ranking system to compare the goals and productivity of individual employees with the productivity and goals of others, is the size of the organization adequate to allow meaningful comparison of similar individuals?

Is the Organization Able to Respond Flexibly to Changing Economic, Political, Social, and Technological Contexts?

John Sommerer noted that the intersection of vision, people, and alignment is addressed by an examination of the organization's agility, flexibility, and adaptability in the face of changing pressures, budgets, and external contexts. Roy Levin emphasized that the rationale for the existence of a research organization is to provide the capacity to deal quickly with the unknown and unexpected. He noted that disruptive technologies, new competitors, and new business models can occur suddenly and must be responded to. Workshop discussants identified the following questions:

- Does the assessment reflect the differences in context for federal, industrial, academic, and national laboratory settings, which involve very different customers, stakeholders, missions, and goals?
- What can be learned from assessment methods applied in other countries?
- Does the organization foster participation in the global R&D community (e.g., by providing resources to prepare publications and attend conferences)?

Appendixes

Appendix A

Agenda for the Workshop

Workshop on Best Practices in Assessment of Research and Development Organizations
Keck Center of the National Academies, Washington, DC
Monday, March 19, 2012

DATA GATHERING SESSION OPEN TO THE PUBLIC

Location: Keck Center, Conference Room 100

7:30–8:00 a.m.	Workshop Registration
8:00–8:15 a.m.	Welcome: **James F. Hinchman**, Deputy Executive Officer and Chief Operating Officer, The National Academies
8:15–8:30 a.m.	Introduction: **John W. Lyons**, Chair, Laboratory Assessments Board, National Research Council

Presentations

8:30–9:00 a.m.	*Impact of Assessments and Merit Reviews on Stakeholders* **James H. Turner**, Counsel and Director of Energy Programs at the Association of Public and Land-grant Universities
9:00–9:30 a.m.	*Assessing R&D Organizations—Perspectives on a Venn Diagram* **John C. Sommerer**, Head, Space Sector, and Johns Hopkins University Gilman Scholar, Johns Hopkins University Applied Physics Laboratory
9:30–10:00 a.m.	*Assessing Sandia Research* **J. Stephen Rottler**, Chief Technology Officer, Vice President, Science and Technology, Sandia National Laboratories
10:00–10:15 a.m.	Break
10:15–10:45 a.m.	*An Industrial Perspective* **William F. Banholzer,** Executive Vice President and Chief Technology Officer, The Dow Chemical Company
10:45–11:15 a.m.	*Managing Innovation at Microsoft Research* **Roy Levin**, Distinguished Engineer and Managing Director, Microsoft Research, Silicon Valley
11:15–11:45: a.m.	*Concepts for Assessment of R&D Organizations* **Gilbert F. Decker**, Consultant

Lunch

11:45 a.m.–1:00 p.m.	Break for Lunch

Discussion Sessions

Location: Assignments in Meeting Folder

1:00–2:30 p.m.	Some Participants Attend Breakout Discussions in Assigned Rooms Some Participants Attend Open-Microphone Discussion in Room 100
2:30–3:00 p.m.	Break

Location: Keck Center, Conference Room 100

3:00–4:00 p.m.	Rapporteurs Summarize Breakout Discussions
4:00 p.m.	Adjournment

Appendix B

List of Registered Workshop Attendees

Workshop on Best Practices in Assessment of Research and Development Organizations
Keck Center of the National Academies, Washington, DC
March 19, 2012

Jeffery Alexander, Center for Science, Technology and Economic Development, SRI International

David Belanger, AT&T Labs

Steven Berner, RAND Corporation

Jennifer Blenkle, Industrial Research Institute

Ali Cinar, Graduate College, Illinois Institute of Technology

Paul Conoval, Northrop Grumman Information Systems

Joseph Corriveau, U.S. Army, Edgewood Chemical Biological Center

Frank Daniel (Dan) Davis, Office of Biotechnology Activities, Office of Science Policy, Office of the Director, National Institutes of Health

Philip DiPietro, National Energy Technology Laboratory, U.S. Department of Energy

Kirk Dohne, National Institute of Standards and Technology

Robert Doudrick, Southern Research Station, U.S. Forest Service

Kelly Ervin, U.S. Army Research Institute

Brian Fairhurst, National High Magnetic Field Laboratory

Sarah Felknor, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention

John Fischer, Office of the Assistant Secretary of Defense for Research and Engineering

Beth Fleming, Engineer Research and Development Center, Environmental Laboratory, U.S. Army Corps of Engineers

Scott Fletcher, U.S. Government Accountability Office

Steve Fluharty, University of Pennsylvania

Stephen Forrest, Office of the Vice President for Research, University of Michigan

Scott Fouse, Advanced Technology Laboratories, Lockheed Martin Corporation

William Frazier, Air Vehicle Engineering, Naval Air Systems Command-Patuxent River

Marilyn Freeman, Deputy Assistant Secretary of the Army for Research and Technology

Reza Ghodssi, Institute for Systems Research, University of Maryland

Linda Gundersen, U.S. Geological Survey

Captain Richard Haberberger, Naval Medical Research Center

Prabhat Hajela, Rensselaer Polytechnic Institute

Nancy Harned, Office of the Deputy Assistant Secretary of the Army for Research and Technology

Janet Harris, Medical Training and Health Information Sciences Research Program, Fort Detrick, U.S. Army Medical Research and Materiel Command

Diana Hicks, School of Public Policy, Georgia Institute of Technology

David Honey, Office of the Director of National Intelligence

Kenneth Jackson, Lawrence Livermore National Laboratory

Robert Johns, Volpe National Transportation Systems Center, U.S. Department of Transportation

Robert Johnson, Civil Aerospace Medical Institute, Federal Aviation Administration

Karen Jones, U.S. Government Accountability Office

William Kiczuk, Raytheon Company

John Kincaid, U.S. Army Capabilities Integration Center

Kevin Knuuti, Engineer Research and Development Center (Cold Regions Research) and Engineering Laboratory, U.S. Army Corps of Engineers

Rama Kotra, U.S. Geological Survey

Glenn Kuback, Sandia National Laboratories

Eric Landree, RAND Corporation

Lesli Livesay, Jet Propulsion Laboratory, National Aeronautics and Space Administration

Bert Macesker, U.S. Coast Guard Research and Development Center

Juanita Marner, Office of the Director, National Institutes of Health

Thom Mason, Oak Ridge National Laboratory

Nan Mattai, Rockwell Collins

David McBride, NASA Dryden Flight Research Center, National Aeronautics and Space Administration

Glenda Mendiola, U.S. Army Communications-Electronics Research, Development and Engineering Center

Stephen Merrill, National Research Council

Terry Michalske, Savannah River National Laboratory, U.S. Department of Energy

Mary Miller, Program Executive Office Soldier, U.S. Army

Debasis Mitra, Bell Labs, Alcatel-Lucent

Margaret Mkenna, U.S. Government Accountability Office

John Montgomery, U.S. Naval Research Laboratory

Reed Mosha, U.S. Army Engineering, Research and Development Center

John Moulden, Turner-Fairbank Highway Research Center, Federal Highway Administration, U.S. Department of Transportation

Rebecca Neustler, The Urban Institute

Ozden Ochoa, U.S. Army Research Laboratory

Timothy O'Connor, Yale University

Emily Ounn, U.S. Government Accountability Office

Peter Plostins, U.S. Army Research Laboratory

Justin Rattner, Intel Corporation

Michael Robertson, Chemical and Biological Defense Division, Science and Technology Directorate, U.S. Department of Homeland Security

John Rumble, R&R Data Services

Lynne Samuelson, Natick Soldier Research, Development and Engineering Center, U.S. Army

Gregory Sayles, National Homeland Security Research Center, U.S. Environmental Protection Agency

Jeffrey Singleton, Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, Secretary of the Army for Acquisition, Logistics and Technology

Michael Skurla, U.S. Army Communications and Electronics Research, Development and Engineering Center

Gregory Smith, National Geospatial-Intelligence Agency

Jill Smith, U.S. Army Communications and Electronics Research, Development and Engineering Center

Joseph Spence, Agricultural Research Service-Beltsville Area, U.S. Department of Agriculture

Maria Stattel, U.S. Government Accountability Office

Sharon Stout, Office of Postsecondary Education Institutional Service, Institutional Service Development Group, U.S. Department of Education

Miron Straf, National Research Council

Mike Strauss, Agricultural Research Service, U.S. Department of Agriculture

Kay Sullivan, RAND Corporation

Erik Svedberg, National Research Council

Philip Turnipseed, National Wetlands Research Center, U.S. Geological Survey

André van Tilborg, Office of Assistant Secretary of Defense for Research and Engineering

Mark Vincent, Office of Policy, Planning, and Evaluation, Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration

Carolyn Wilson, Center for Biologics Evaluation and Research, U.S. Food and Drug Administration

Martin Wybourne, Dartmouth College

Harold Zenick, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency

Appendix C

Biographical Sketches of the Members of the Planning Committee and Panel for Review of Best Practices in Assessment of Research and Development Organizations

JOHN W. LYONS (NAE), *Chair,* is a Distinguished Research Fellow at the Center for Technology and National Security Policy at the National Defense University. In 1993, he was appointed the first permanent director of the Army Research Laboratory (ARL). At ARL he managed a broad array of science and technology programs: electronics, information science and technology, armor/armaments, soldier systems, air and ground vehicle technology, and survivability/lethality analysis. In 1990, Dr. Lyons was appointed Director of the National Institute of Standards and Technology. He has received the Department of Commerce Gold Medal and the Department of the Army's Decoration for Exceptional Civilian Service. He has published 4 books and more than 60 papers, and he holds a dozen patents. Dr. Lyons also has served on many boards and commissions. He received his A.B. degree from Harvard University and his A.M. and Ph.D. degrees from Washington University, all in chemistry.

EDWARD A. BROWN is a Principal Staff Member in the Center for Integrated Intelligence Systems of the MITRE Corporation, where he is concentrating on innovative techniques for assisting member organizations of the intelligence community (IC) in the management of their science and technology (S&T) programs. His expertise spans the broad area of managing government S&T enterprises. He went to MITRE after a 33-year career as a government employee within the Army's research and development (R&D) community. One of his final assignments as a civil servant was as a member of the Director of Central Intelligence's Strategic S&T Management Task Force, which was chartered to develop new techniques for managing the IC's S&T enterprise. Dr. Brown is now assisting the IC to implement the results of the task force work in his current position with MITRE. He has supported S&T management improvement efforts in a variety of government agencies and served for 4 years on the Army Laboratory Assessment Group reporting to the Deputy Assistant Secretary of the Army for Research and Technology. Before arriving at MITRE, he was the Director for Special Projects at the U.S. Army Research Laboratory (ARL). In that position he supported the ARL Director in administering and coordinating activities relevant to the management of both the laboratory and its technical program. He was responsible for much of ARL's groundbreaking work in performance measurement and business planning as it applies to R&D organizations. For his work in innovative R&D management, Dr. Brown was awarded the Army's Superior Civilian Service Award. Dr. Brown received his bachelor's degree from Washington and Lee University and his master's and doctoral degrees from New York University, all in physics.

W. WARNER BURKE is Edward Lee Thorndike Professor of Psychology and Education Program Coordinator, Graduate Programs in Social-Organizational Psychology, and

Chair of the Department of Organization and Leadership, Teachers College, Columbia University. He is currently engaged in teaching, research, and consulting. He teaches leadership, organizational dynamics and theory, and organization change and consultation. His research focuses on multirater feedback, leadership, and organization change. Dr. Burke's consulting experience has been with a variety of organizations in business-industry, education, government, religion, medical systems, and professional services firms, and he has served as senior adviser to the strategy and organization change practice of IBM Global Business Services. Prior to his move to Teachers College, Dr. Burke was professor of management and chair of the Department of Management at Clark University. Previously he had been an independent consultant as well as serving in various other capacities. Dr. Burke is the author of more than 150 articles and book chapters on organization development, training, change and organizational psychology, and conference planning; he has contributed as an author, co-author, editor, and/or co-editor of 19 books. His most recent (2011) book, published by Sage, is *Organization Change: Theory and Practice, Third Edition.* He received his B.A. from Furman University and his M.A. and Ph.D. from the University of Texas at Austin.

ROSS B. COROTIS (NAE), PE, is Denver Business Challenge Professor of Engineering at the University of Colorado at Boulder. He has research interests in the application of probabilistic concepts and decision perceptions for civil engineering problems, and in particular their application to societal trade-offs for hazards in the built infrastructure. His current research emphasizes the coordinated roles of engineering and social science with respect to framing and communicating societal investments for long-term risks and resiliency. Dr. Corotis was on the faculty at Northwestern University for 11 years; established the Department of Civil Engineering at the Johns Hopkins University, where he was also the Associate Dean of Engineering; and was the Dean of the College of Engineering and Applied Science at the University of Colorado at Boulder. He has numerous research, teaching, and service awards; chaired several committees on structural safety for the American Society of Civil Engineers (ASCE) and the American Concrete Institute (ACI); served as editor of the international journal *Structural Safety* and the ASCE *Journal of Engineering Mechanics*; and chaired the Executive Committee of the International Association for Structural Safety and Reliability. For the National Research Council, he served on the Building Research Board and the steering committee of the Disasters Roundtable, and he chaired the Panel on Assessment of the NIST Building and Fire Research Laboratory. He is the founding chair of the Committee on NIST Technical Programs and past Chair of the Civil Engineering Section of the National Academy of Engineering. Dr. Corotis is a registered professional engineer in Illinois, Maryland, and Colorado; a registered structural engineer in Illinois; and a Distinguished Member of ASCE. He is the author of more than 200 publications. He received his B.S., M.S., and Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology (MIT).

WILLIAM W. CRAIG is the Director of Laboratory Directed Research and Development in the Institutional Science and Technology Office at the Lawrence Livermore National Laboratory (LLNL) and Payload Manager for the NuSTAR Small Explorer Mission at the University of California, Berkeley. He is also the Aerospace Program Manager at the

University of California Space Sciences Laboratory, Berkeley. Dr. Craig previously served in the following positions: Deputy Director, Institutional Science and Technology Office, LLNL; Chief Scientist, Physics and Advanced Technologies Directorate, LLNL; Technical Advisor in the Domestic Nuclear Detection Office, U.S. Department of Homeland Security; Group Leader at the Kavli Institute for Particle Astrophysics and Cosmology and Hansen Experimental Physics Laboratory, at Stanford University; and in a number of other positions at LLNL and at the Columbia Astrophysics Laboratory, Columbia University. Dr. Craig received his B.A. and M.S. degrees in physics and his Ph.D. in astrophysics from the University of California, Berkeley.

C. WILLIAM GEAR (NAE) is Senior Scientist, Chemical Engineering, at Princeton University and President Emeritus of the NEC Research Institute. Dr. Gear's National Academy of Engineering (NAE) citation is for "seminal work in methods and software for solving classes of differential equations and differential-algebraic equations of significance in applications." His primary interest is scientific computation, particularly involving differential equations, and even more specifically, stiff equations and differential-algebraic equations. More recently he has become interested in numerical techniques applied to computer vision. Dr. Gear received his B.A. and M.A. degrees from Cambridge University and his M.S. and Ph.D. degrees from the University of Illinois at Urbana-Champaign, all in mathematics.

WESLEY L. HARRIS (NAE) is the Charles Stark Draper Professor of Aeronautics and Astronautics and the Director of the Lean Sustainment Initiative at the Massachusetts Institute of Technology (MIT). Before his appointment as Associate Provost, Dr. Harris served as head of MIT's Department of Aeronautics and Astronautics from 2003 to 2008. From 1972 to 1985, he taught and held several administrative positions at MIT. Dr. Harris served as Dean of the School of Engineering at the University of Connecticut from 1985 to 1990, and as Vice President and Chief Administrative Officer of the University of Tennessee Space Institute from 1990 to 1993. As NASA's associate administrator for aeronautics from 1993 to 1995, he was responsible for all programs, facilities, and personnel in aeronautics at NASA. He earned his B.S. in aerospace engineering at the University of Virginia and his M.A. and Ph.D. in aerospace and mechanical sciences at Princeton University, on whose board of trustees he later served.

ELENI KOUSVELARI is a Senior Scientist at the Biological and Materials Sciences Center, Sandia National Laboratories. She is an expert in the direction and organization of bioengineering and translational research. Before joining Sandia National Laboratories, she was the Associate Director for Biotechnology and Innovation at the National Institute of Dental and Craniofacial Research (NIDCR) at the National Institutes of Health (NIH). Before that, she held a number of positions at the NIDCR, including Acting Director of the Center for Biotechnology and Innovation, Acting Program Director and Program Director for a variety of programs, and Chief of the Cellular and Molecular Biology, Physiology and Biotechnology Branch and the Biomaterials, Biomimetics and Tissue Engineering Branch. Before her service at NIH, Dr. Kousvelari held a number of positions at the School of Dentistry at Temple University, the School of Dental Medicine at the University of Connecticut, and the School of Graduate Dentistry at Boston University. She has received numerous awards and is a member of the American Association for the Advancement of Science, International Association for Dental Research, American Society of Cell Biology, Society of Biomaterials, and American Dental Association. Dr. Kousvelari received her D.D.S. degree from the Athens University Medical and Dental School, her M.Sc./C.A.G.S.P. degree in prosthodontics from the Boston University School of Graduate Dentistry, and her D.Sc. in oral biology from the Boston University School of Graduate Dentistry.

BERNARD S. MEYERSON (NAE) is the Vice President for Innovation at IBM, and he leads IBM's Global University Relations Function within IBM's Corporate Headquarters organization. He is also responsible for the IBM Academy, a self-governed organization of 800 executives and senior technical leaders from across IBM, having been appointed to this position in December 2005. In 1980, Dr. Meyerson joined IBM Research as a staff member, leading the development of silicon, germanium, and other high-performance technologies over a period of 10 years. In 1992, he was appointed an IBM Fellow by IBM's Chairman, and in 2003 he assumed operational responsibility for IBM's global semiconductor research and development efforts. In that role Dr. Meyerson led the world's largest semiconductor development consortium—members being IBM, Sony, Toshiba, AMD, Samsung, Chartered Semiconductor, and Infineon. He has received numerous awards for his work. Dr. Meyerson was cited as Inventor of the Year by the New York State Legislature in 1998 and was recognized as United States Distinguished Inventor of the Year by the U.S. IP Law Association and the Patent and Trademark Office in 1999. He was most recently recognized in May 2008 as Inventor of the Year by the New York State Intellectual Property Law Association. He has published more than 180 papers and owns more than 40 patents. Dr. Meyerson has a Ph.D. in physics from the City College of New York.

ELSA REICHMANIS (NAE) is a professor in the Department of Chemical and Biomolecular Engineering at the Georgia Institute of Technology. Her National Academy of Engineering (NAE) citation is for "the discovery, development, and engineering leadership of new families of lithographic materials and processes that enable VLSI [very large scale integration] manufacturing." Her research is at the interface of chemistry, materials science, optics, electronics, and engineering, spanning the range from fundamental concept to technology development and implementation. Her research is focused on organic and polymer materials design for electronic and photonic applications. She is experienced in leading cross-cultural, multidisciplinary research teams and in generating value for intellectual property through patent and technology license agreements. Dr. Reichmanis has published extensively; has organized national and international workshops, symposia, and conferences; and has mentored students and post-doctoral fellows and taught courses. She has received numerous awards and has more than 150 publications, more than 15 patents, and 5 books to her credit. Dr. Reichmanis received her B.S. in chemistry and her Ph.D. in organic chemistry from Syracuse University.

JOEL M. SCHNUR is a professor in the College of Science at George Mason University (GMU). Dr. Schnur retired from the Naval Research Laboratory (NRL) in 2008. His role at GMU is to stimulate new science of “impact” across department lines in GMU’s College of Science and to initiate collaborations in the College of Engineering. As Director of the Center for Bio/Molecular Science and Engineering at NRL, Dr. Schnur provided scientific direction and management in the areas of complex bio/molecular systems with the aim of modifying structures in ways that will lead to the development of useful devices, techniques, and systems of use for the Navy and the Department of Defense. Dr. Schnur’s research interests focus on understanding the relationship between the structure of molecules and observed macroscopic phenomena. This interest has led to his publications in the areas of critical phenomena, liquid crystals, picosecond spectroscopy, high-pressure and shock-related phenomena, self-assembly of biologically derived microstructures, and, recently, bio-based power sources bioinformatics, systems biology, and genomics. Dr. Schnur has more than 150 publications and issued patents, which have led to more than 3,000 citations; 20 of his more than 40 patents have produced or are currently producing royalties. He received his A.B. in chemistry from Rutgers University and his M.S. and Ph.D. in physical chemistry from Georgetown University.

LYLE H. SCHWARTZ (NAE) retired from government service in 2004, after 18 years as a member of the Senior Executive Service. In his last position, as Director of the Air Force Office of Scientific Research (AFOSR), he guided the management of the entire basic research investment for the U.S. Air Force. He led a staff of more than 200 scientists, engineers, and support people in Arlington, Virginia, and two foreign technology offices, in London and Tokyo. As Director, he was charged with maintaining the technological superiority of the Air Force. Each year, AFOSR selects, sponsors, and manages revolutionary basic research relevant to Air Force needs. The investment of AFOSR in basic research programs is distributed across 300 academic institutions, 145 industry contracts, and more than 150 research efforts within the Air Force Research Laboratory. Prior to becoming AFOSR’s Director, Dr. Schwartz directed the AFOSR's Aerospace and Materials Sciences Directorate. From 1984 to 1997, he served as Director of the Materials Science and Engineering Laboratory at the National Institute of Standards and Technology. In that position, he managed programs in both structural and functional materials, with research emphasis ranging from basic to applied. From 1989 to 1997, he led the multiagency materials research coordination committee for the Office of Science and Technology Policy, and was responsible for the development of the Presidential Initiative on Advanced Materials and Processing launched in 1991. Previously, he taught and served as Director of the Materials Research Center at Northwestern University. He has written more than 85 technical papers and is a co-author of two textbooks in materials science and engineering. He received his B.S. in science engineering and Ph.D. in materials science from Northwestern University.

Appendix D

Biographical Sketches of Workshop Presenters

WILLIAM F. BANHOLZER (NAE) is the Executive Vice President at Ventures, New Business Development and Licensing, and Chief Technology Officer (CTO) for the Dow Chemical Company. He is a member of Dow's Executive Leadership Committee, which is responsible for corporate strategy and financial performance, and is also a member of the Strategy Board, responsible for the review and approval of the Company's strategy and resource allocation decisions. As CTO, Dr. Banholzer has responsibility for driving innovation, for value creation, and for leading Dow's global research and development activities, directing an annual budget of $1.7 billion. Dr. Banholzer co-leads Dow's Innovation and Growth Team, which oversees all of Dow's Innovation programs, including new growth platforms. In addition, he serves on Dow's Venture Capital Board, the Dow Kokam Board, Dow AgroScience's Members Committee, and the Dow Foundation. He is a member of the board of directors for the Dow Corning Corporation, serving on the Corporate Responsibility Committee. Prior to arriving at Dow, Dr. Banholzer had a 22-year career with General Electric Company (GE); as Vice President of Global Technology at GE Advanced Materials, he was responsible for worldwide technology and engineering. During his GE career, Dr. Banholzer was honored with GE's Bronze, Silver, and Gold Patent Awards; GE Superabrasives' Leadership Award; GE Plastics' CEO Six Sigma Award; and election to the Whitney Gallery of Technical Achievers. In 2002, he was elected to the U.S. National Academy of Engineering. Dr. Banholzer serves on advisory boards for chemistry and chemical engineering at the University of California, Berkeley, and for the chemical engineering department at the University of Wisconsin, and he serves on the National Research Council's Board on Energy and Environmental Systems. He is a member of the American Chemical Society and the American Institute of Chemical Engineers. He holds 16 U.S. patents and has more than 80 publications. Dr. Banholzer earned a bachelor's degree in chemistry from Marquette University and master's and doctorate degrees in chemical engineering from the University of Illinois.

GILBERT F. DECKER is a private consultant for several clients, including the U.S. Army, the U.S. Navy, and several corporations. Recently (May 2010 to February 2011), Mr. Decker co-chaired a commision appointed by the Secretary of the Army to conduct an in-depth review of the Army acquisition process, from requirements definition to production, and to provide findings and recommendations for improvements in quality and efficiency. Previously, Mr. Decker served as a commissioned officer in the U.S. Army and as a colonel in the U.S. Army Reserve. Before becoming a private consultant, he held several distinguished positions, including the following: President and Chief Executive Officer (CEO) of the Penn Central Federal Systems Company; Vice President and General Manager of the Defense Systems Group of TRW, Inc.; President and CEO of Acurex Corporation; President and CEO of ESL, Inc.; and Assistant Secretary of the

Army for Research, Development, and Acquisition, a position in which he served from 1993 through 1997. After his service as Assistant Secretary, he served as Executive Vice President for Engineering, Manufacturing, and Program Management of Walt Disney Imagineering. Honors presented to Mr. Decker include the Distinguished Public Service Medal from the Department of Defense, the Distinguished Civilian Service Medal from the Department of the Army, the Meritorious Service Medal from the U.S. Army, and the Distinguished Alumni Award from the Johns Hopkins University. Mr. Decker currently serves on the National Advisory Council for the Johns Hopkins University Whiting School of Engineering. He also serves on the advisory board of the Carnegie Mellon University Software Engineering Institute. He previously served on the National Research Council's Board on Army Science and Technology (BAST). He is the Vice President and a director of the Hertz Foundation. He was formerly a director of Alliant TechSystems for 10 years, a director of Anteon Corporation for 10 years, and a director of the Allied Defense Group for 10 years. He served as a trustee for the Association of the U.S. Army and is a sustaining member. Mr. Decker holds a B.S. in electrical engineering from the John Hopkins University and an M.S. in operations research from Stanford University. He undertook his military education as a U.S. Army Reserve Officer at the U.S. Army Command and General Staff College as well as at the Industrial College of the Armed Forces.

ROY LEVIN is a Distinguished Engineer and Managing Director of Microsoft Research, Silicon Valley, which he co-founded in August 2001. The laboratory at present numbers approximately 75 researchers working in the area of distributed computing and related disciplines and operates in a highly collaborative style that embraces the technical spectrum from theory to practice. From 1996 until he joined Microsoft, Dr. Levin was the Director of the Digital/Compaq Systems Research Center in Palo Alto, California. Previously he had been a senior researcher in the Center since its founding in 1984. During those years he was a primary contributor and project leader for the Vesta software configuration management system and for the Topaz multiprocessor programming environment and its micro-kernel operating system. Before joining Digital, Dr. Levin was a researcher at Xerox's Palo Alto Research Center, where he was a principal developer and project co-leader of Cedar, an experimental programming environment for high-performance workstations. He was also a developer of Grapevine, a landmark electronic mail system. Dr. Levin received his Ph.D. in computer science from Carnegie Mellon University and his B.S. in mathematics from Yale University. He is a Fellow of the Association for Computing Machinery (ACM), a former chair of its Special Interest Group on Operating Systems (SIGOPS), and a co-recipient of the ACM SIGOPS 2008 Hall of Fame Award. He is the author or a co-author of approximately 25 technical papers, books, and patents.

J. STEPHEN ROTTLER is Chief Technology Officer and Vice President for Science and Technology at Sandia National Laboratories (SNL), located in Albuquerque, New Mexico, and Livermore, California. Dr. Rottler is the executive responsible for leadership and management of corporate research and development and capabilities stewardship at SNL. He is also responsible for leadership of technology transfer and strategic research relationships with universities, industry, and the State of New Mexico.

In his previous position as Chief Engineer for Nuclear Weapons and Vice President for Weapon Engineering and Product Realization, Dr. Rottler was the Central Technical Authority for nuclear weapons and led all nuclear weapons engineering and production activities at Sandia. Prior to serving in that position, Dr. Rottler served in a number of senior leadership positions at the Laboratories. He has been responsible for nuclear warhead system engineering and integration, development of high-performance electronic systems, and system analyses and assessments for SNL and National Nuclear Security Administration senior management. He also managed organizations and programs responsible for the research, development, and application of advanced computational and experimental techniques in the engineering sciences. As a member of the SNL technical staff, Dr. Rottler was part of a research team that developed multidimensional radiation-hydrodynamics simulation codes for nuclear weapons applications, and he led projects that supported the development of advanced nuclear and conventional weapons concepts. He is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA), a member of the Institute's Board of Directors, and a past Chair of the AIAA's Technical Committee on Management. He is a recipient of the Department of the Air Force Award for Exemplary Civilian Service. Dr. Rottler is a Fellow of Seminar XXI at the Massachusetts Institute of Technology. He is currently serving or has served on the board of directors of the United Kingdom Atomic Weapons Establishment, New Mexico Humanities Council, Albuquerque Explora Science Museum, and Technology Ventures Corporation. He is a member of the external advisory board for the Texas A&M University Dwight Look College of Engineering. He has led or served on independent review panels for the U.S. Navy Strategic Systems Programs Office and the United Kingdom Atomic Weapons Establishment. Dr. Rottler received his B.S., M.S., and Ph.D. degrees in nuclear engineering from Texas A&M University in 1980, 1982, and 1984, respectively. He has published papers, reports, and conference presentations on the development and application of computational radiation-hydrodynamics codes.

JOHN C. SOMMERER leads the Space Sector at the Johns Hopkins University Applied Physics Laboratory (APL), which provides the Department of Defense and the National Aeronautics and Space Administration (NASA) with essential capabilities in combat and guided missile systems, air and missile defense, space science and exploration, strategic systems test and evaluation, submarine security, information technology and communications systems, modeling and simulation, and research and development. Since August 2008, Dr. Sommerer has been responsible for APL's Civilian Space Area and National Security Space Business Area. APL is responsible for executing NASA's MESSENGER (Mercury Surface, Space Environment, Geochemistry and Ranging) mission to Mercury, New Horizons mission to Pluto, STEREO (Solar Terrestrial Relations Observatory) heliophysics mission, and TIMED (Thermospere Ionosphere Mesosphere Energetics and Dynamics) Earth science mission (all under way); Radiation Belt Storm Probes mission to explore the Van Allen Belts (in spacecraft development); and Solar Probe Plus mission to explore the Sun's outer atmosphere (in engineering and mission design). APL is Technical Direction Agent for the Precision Tracking Space System, a national security mission sponsored by the Missile Defense Agency. Prior to his current assignment, Dr. Sommerer was APL's Director of Science and Technology and Chief Technology Officer, managing the laboratory's research and development program and S&T strategy; overseeing its Office of Technology Transfer and its support of the educational programs of the Johns Hopkins Whiting School of Engineering; and serving as primary technical liaison with the academic divisions of the university. He chaired APL's Science and Technology Council, charged with ensuring that the laboratory always has the technical capabilities required to meet its mission. He has been with APL since 1980, holding technical and management positions in five of its departments and leading the development of an APL strategic plan for its core mission areas that identified three new initiatives now accounting for 30 percent of APL's program activities and over 100 percent of APL's program growth since 1999. He served as head of the Milton S. Eisenhower Research and Technology Center for 9 years; under his leadership, it more than tripled in size, and enabled APL to enter two new areas of service to the nation. Dr. Sommerer received B.S. (summa cum laude) and M.S. (with honors) degrees in systems science and mathematics from Washington University in St. Louis, an M.S. (with honors) in applied physics from the Johns Hopkins University, and a Ph.D. in physics from the University of Maryland. Prior to assuming executive responsibilities, he established an international reputation in nonlinear dynamics, making both theoretical and experimental contributions to the field. His personal research has been featured on the covers of both *Science* and *Nature*. He was a member of the editorial board of *The Physical Review* (1999-2005). In 2011, Dr. Sommerer was named as one of the inaugural Daniel Coit Gilman Scholars of the Johns Hopkins University, designating him as one of the foremost thought leaders within the University. He was also elected to the International Academy of Astronautics. He serves on multiple standing technical advisory bodies for the U.S. government, including the Naval Research Advisory Committee (he served a 2-year term as Vice Chair and a 2-year term as Chair), reporting to the Secretary of the Navy. He has also been a member of three National Research Council (NRC) standing boards and committees, as well as having participated in numerous ad hoc NRC studies; he was named a National Associate of the NRC in 2008. He has received a number of awards, including being named Maryland's Distinguished Young Scientist in 1994. He was an adviser to the Howard County, Maryland, new business incubator, NeoTech, during its formation, and he served as a director of the Jim Rouse Entrepreneurial Fund.

JAMES H. TURNER is the Counsel and Director of Energy Programs at the Association of Public and Land-grant Universities and the former chief counsel to the U.S. House of Representatives Committee on Science and Technology. Mr. Turner studied mathematics at Westminster College, social ethics at Yale Divinity School, and law at Georgetown University. He completed the Senior Managers in Government Program at the Harvard Kennedy School, is on the board of Oak Ridge Associated Universities, and was Academic Vice Chair for the President's Advisory Committee for the Carnegie Mellon Heinz College. Recognizing the need to link technical expertise with federal policy, he set up a lecture series of senior Washington, D.C., officials for the Washington internship program for the Massachusetts Institute of Technology (MIT). Later, Dean Richard Miksad of the University of Virginia expanded the program to include the University of Virginia. Mr. Turner advises the program, helps interns find placements, and organizes a summer speaker series. He serves as a trustee of the University of Virginia School of

Engineering and Applied Science and as chair of the advisory board of its Department of Science, Technology and Society. In 2010, to honor his 10 years of service to the S&T Policy Internship program, the alumni of the the University of Virginia program named the annual end-of-summer research symposium after him.