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FACILITATING INTERDISCIPLINARY RESEARCH

Committee on Facilitating Interdisciplinary Research
Committee on Science, Engineering, and Public Policy

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Preface

Over the last decade, the National Academies Committee on Science, Engineering, and Public Policy (COSEPUP) has issued a series of reports on how science and engineering are performed and supported in the United States and how future generations of scientists are trained and educated.[1] A point made by each report is that science and engineering research continually evolves beyond the boundaries of single disciplines and offers employment opportunities that require not only *depth* of knowledge but also *breadth* of knowledge, integration, synthesis, and an array of skills. Several reports suggested that a greater emphasis on interdisciplinary research and training would be consistent with those findings.

In May 2003, the National Academies and the W.M. Keck Foundation announced the National Academies Keck *Futures Initiative*, a program designed to realize the full potential of interdisciplinary research (IDR). Specifically, the *Futures Initiative* was created to "stimulate new modes of inquiry and break down the conceptual and institutional barriers to interdisciplinary research that could yield significant benefits to science and society."

As indicated by Robert A. Day, chairman and chief executive officer of the W. M. Keck Foundation, "The *Futures Initiative* is designed to create a

[1]See, for example, *Science, Technology, and the Federal Government: National Goals for a New Era* (1993), which emphasized the importance of human resources for the scientific enterprise, and *Reshaping the Graduate Education of Scientists and Engineers* (1995), which urged expanded training opportunities for students to prepare them not only for academic careers but also for wider employment opportunities. Later reports dealt with changing careers and mentoring students in science and engineering.

powerful, ongoing forum where the best and brightest minds from across the disciplines of science, technology, and medical research can come together and ask each other, 'What if . . . ?' More than that, they can then secure the funds necessary to pursue ideas and conduct follow-on research. Training individuals who are conversant in ideas and languages of other fields is central to the continued march of scientific progress in the 21st century. The W. M. Keck Foundation is proud to participate in this important effort."

As part of the *Futures Initiative*, the Keck Foundation asked the National Academies to review the state of interdisciplinary research and education in science and engineering and recommend ways to facilitate them. Accordingly, COSEPUP, under the aegis of the National Academies, created the Committee on Facilitating Interdisciplinary Research, whose members were drawn from government, academe, and industry and had long experience in leading and performing IDR.[2] The committee was charged with the following tasks:

1. Review proposed definitions of interdisciplinary research, including similarities and differences from research characterized as cross-disciplinary, intradisciplinary, and multidisciplinary, and develop measures to determine whether research is interdisciplinary or not.
2. Identify and analyze current structural models of interdisciplinary research.
3. Identify and analyze the policies and procedures of Congress, funding organizations, and institutions that encourage or discourage interdisciplinary research.
4. Compare and contrast current structural models and policies and procedures in academic and nonacademic settings as well as traditional and nontraditional academic settings that encourage or discourage interdisciplinary research.
5. Identify measures that can be used to evaluate the impact on research, graduate students and postdoctoral scholars, and researchers expected from their engagement in greater interdisciplinary research and cross-professional opportunities.
6. Develop findings and conclusions as to the current state of interdisciplinary research and the factors that encourage (or discourage) it in academic, industry, and federal laboratory settings.
7. Provide recommendations to academic institutions and public and private sponsors of research as to how to better stimulate and support interdisciplinary research.

[2]Biographical information on members of the committee are listed in Appendix A.

The committee's methods and the framework for this report are provided in the "Note to the Reader" that follows the Executive Summary. In sum, the committee based its analysis of how to facilitate IDR on its Convocation on Facilitating IDR, surveys, focus groups, interviews with scholars, and an extensive literature review.

The committee was hampered in its attempt to compare models and policies that encourage IDR by a lack of recent published information. There is a considerable history of research, but the committee found insufficient evidence to answer such questions as, Which, if any, emerging IDR fields and subfields should be strengthened? What technologies and instruments are most likely to generate new ID fields and subfields? Where (if anywhere) should the government increase its investment in IDR? This report is the latest in a growing literature on models and policies that situates the discussion in the current context of science and engineering, and it formally recommends increased research to provide the necessary answers.

Similarly, in attempting to compare academic and nonacademic research practices, the committee found substantial asymmetries. Interdisciplinarity has long been accepted and familiar in many industrial and government laboratories and other nonacademic settings; such settings traditionally emphasize teams and problem-driven research, and they permit researchers to move easily between laboratories, to share their skills, and to acquire new ones. In academe, however, such collaboration is often impeded by administrative, funding, and cultural barriers between departments, by which most research and teaching activities are organized. For that reason and because the highest concentration of scholarly expertise is found in universities, this report focuses primarily on facilitating IDR in academe.

The study identified academic institutional customs that create a small but persistent "drag" on researchers who would like to do interdisciplinary research and teaching. They include especially the academic promotion and reward system and the department-based budgeting structures of universities. The committee concluded that IDR nevertheless plays an essential and growing role in permitting researchers to venture beyond the frontiers of their own disciplines and address questions of ever-increasing complexity and societal urgency. The committee identified "best practices" identified in its investigation that can be applied by those who wish to facilitate IDR, including undergraduate and graduate students, postdoctoral fellows, faculty members, researchers, funding organizations, academic and nonacademic institutions, and disciplinary societies. In some of the cases, institutions have experimented with substantial alteration of the traditional academic structures or even replacement with new structures and models to reduce barriers to IDR. It also found that improved evaluation tools, such

as the ability to provide a broader peer review of interdisciplinary proposals and publication submissions, can greatly assist those who wish to conceptualize, fund, and administer IDR. More best practices, of course, exist than are provided in this report.

In conclusion, this report is a "call to action" for all those who perform, administer, support, and organize interdisciplinary research and training. Its purpose is to facilitate collaborative practices that can increase the productivity of science and engineering. The majority of the report suggests "incremental" changes that will facilitate interdisciplinary research. In Chapter 9, however, the committee provides suggestions for "transformative" changes for those institutions who are willing to experiment with new approaches. Research partnerships must be especially tailored to address scientific and societal challenges in innovative ways. The purpose of this report is not to privilege the pursuit of IDR over disciplinary research, but rather to seek to provide suggestions to those interested or engaged in interdisciplinarity to optimize its effectiveness and strengthen both IDR and the disciplinary foundations from which it springs.

Nancy C. Andreasen
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Next, we would like to thank the reviewers of this report. This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC'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 report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

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Executive Summary

Interdisciplinary research (IDR) can be one of the most productive and inspiring of human pursuits—one that provides a format for conversations and connections that lead to new knowledge. As a mode of discovery and education, it has delivered much already and promises more—a sustainable environment, healthier and more prosperous lives, new discoveries and technologies to inspire young minds, and a deeper understanding of our place in space and time. Despite the apparent benefits of IDR, researchers interested in pursuing it often face daunting obstacles and disincentives. Some of them take the form of personal communication or "culture" barriers; others are related to the tradition in academic institutions of organizing research and teaching activities by discipline-based departments—a tradition that is commonly mirrored in funding organizations, professional societies, and journals.

Under the sponsorship of the Keck Foundation, the National Academies Committee on Facilitating Interdisciplinary Research examined the scope of IDR. It drew conclusions and made recommendations based on the committee's deliberations and on suggestions it received from undergraduate and graduate students, postdoctoral scholars, researchers, academic and nonacademic institutional leaders, funding organizations, and professional societies at its convocation and via its survey; the focus groups held at the National Academies Keck *Futures Initiative* Conference; and interviews with leading scholars.

The recommendations proposed here can help students, postdoctoral scholars, researchers, institutions, funding organizations, professional societies, and those who evaluate research to help IDR to reach its full potential.

FINDINGS

The committee's 15 findings are organized here in three categories: the definition of IDR, its current situation, and the changes needed to facilitate it.

Definition

1. Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice.

Current Situation

2. IDR is pluralistic in method and focus. It may be conducted by individuals or groups and may be driven by scientific curiosity or practical needs.

3. Interdisciplinary thinking is rapidly becoming an integral feature of research as a result of four powerful "drivers": the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a single discipline, the need to solve societal problems, and the power of new technologies.

4. Successful interdisciplinary researchers have found ways to integrate and synthesize disciplinary depth with breadth of interests, visions, and skills.

5. Students, especially undergraduates, are strongly attracted to interdisciplinary courses, especially those of societal relevance.

6. The success of IDR groups depends on institutional commitment and research leadership. Leaders with clear vision and effective communication and team-building skills can catalyze the integration of disciplines.

Challenges to Overcome

7. The characteristics of IDR pose special challenges for funding organizations that wish to support it. IDR is typically collaborative and

involves people of disparate backgrounds. Thus, it may take extra time for building consensus and for learning new methods, languages, and cultures.

8. Social-science research has not yet fully elucidated the complex social and intellectual processes that make for successful IDR. A deeper understanding of these processes will further enhance the prospects for creation and management of successful IDR programs.

Changes Needed

9. In attempting to balance the strengthening of disciplines and the pursuit of interdisciplinary research, education, and training, many institutions are impeded by traditions and policies that govern hiring, promotion, tenure, and resource allocation.

10. The increasing specialization and cross-fertilizations in science and engineering require new modes of organization and a modified reward structure to facilitate interdisciplinary interactions.

11. Professional societies have the opportunity to facilitate IDR by producing state-of-the-art reports on recent research developments and on curriculum, assessment, and accreditation methods; enhancing personal interactions; building partnerships among societies; publishing interdisciplinary journals and special editions of disciplinary journals; and promoting mutual understanding of disciplinary methods, languages, and cultures.

12. Reliable methods for prospective and retrospective evaluation of interdisciplinary research and education programs will require modification of the peer-review process to include researchers with interdisciplinary expertise in addition to researchers with expertise in the relevant disciplines.

Lessons from Industry and National Laboratories

13. Industrial and national laboratories have long experience in supporting IDR. Unlike universities, industry and national laboratories organize by the problems they wish their research enterprise to address. As problems come and go, so does the design of the organization.

14. Although research management in industrial and government settings tends to be more "top-down" than it is at universities, some of its lessons may be profitably incorporated into universities' IDR strategies.

15. Collaborative interdisciplinary research partnerships among universities, industry, and government have increased and diversified rapidly. Although such partnerships still face significant barriers, well-documented studies provide strong evidence of both their research benefits and their effectiveness in bringing together diverse cultures.

RECOMMENDATIONS

On the basis of its findings, the committee offers the following recommendations. They are listed by category of people and organizations involved in interdisciplinary research, education, and training. The committee does not necessarily urge interdisciplinary research activities for all institutions and individuals, but, for parties that are interested in implementing or improving such activities, the committee provides the following recommendations.

The majority of the recommendations the committee makes to facilitate interdisciplinary research are "incremental"; however, the committee provides suggestions for "transformative" changes for those institutions willing to experiment with new approaches. Most of these are described briefly here in the section entitled "academic institutional structures," but very specific ideas are provided in Chapter 9 that expand upon these recommendations.

Students

S-1: *Undergraduate students* should seek out interdisciplinary experiences, such as courses at the interfaces of traditional disciplines that address basic research problems, interdisciplinary courses that address societal problems, and research experiences that span more than one traditional discipline.

S-2: *Graduate students* should explore ways to broaden their experience by gaining "requisite" knowledge in one or more fields in addition to their primary field.

Postdoctoral Scholars

P-1: Postdoctoral scholars can actively exploit formal and informal means of gaining interdisciplinary experiences during their postdoctoral appointments through such mechanisms as networking events and internships in industrial and nonacademic settings.

P-2: Postdoctoral scholars interested in interdisciplinary work should seek to identify institutions and mentors favorable to IDR.

Researchers and Faculty Members

R-1: Researchers and faculty members desiring to work on interdisciplinary research, education, and training projects should immerse themselves in the languages, cultures, and knowledge of their collaborators in IDR.

R-2: Researchers and faculty members who hire postdoctoral scholars from other fields should assume the responsibility for educating them in the new specialties and become acquainted with the postdoctoral scholars' knowledge and techniques.

Educators

A-1: Educators should facilitate IDR by providing educational and training opportunities for undergraduates, graduate students, and postdoctoral scholars, such as relating foundation courses, data gathering and analysis, and research activities to other fields of study and to society at large.

Academic Institutions' Policies

I-1: Academic institutions should develop new and strengthen existing policies and practices that lower or remove barriers to interdisciplinary research and scholarship, including developing joint programs with industry and government and nongovernment organizations.

I-2: Beyond the measures suggested in I-1, institutions should experiment with more innovative policies and structures to facilitate IDR, making appropriate use of lessons learned from the performance of IDR in industrial and national laboratories.

I-3: Institutions should support interdisciplinary education and training for students, postdoctoral scholars, researchers, and faculty by providing such mechanisms as undergraduate research opportunities, faculty team-teaching credit, and IDR management training.

I-4: Institutions should develop equitable and flexible budgetary and cost-sharing policies that support IDR.

Team Leaders

T-1: To facilitate the work of an IDR team, its leaders should bring together potential research collaborators early in the process and work toward agreement on key issues.

T-2: IDR leaders should seek to ensure that each participant strikes an appropriate balance between leading and following and between contributing to and benefiting from the efforts of the team.

Funding Organizations

F-1: Funding organizations should recognize and take into consideration in their programs and processes the unique challenges faced by IDR with respect to risk, organizational mode, and time.

F-2: Funding organizations, including interagency cooperative activities, should provide mechanisms that link interdisciplinary research and education and should provide opportunities for broadening training for researchers and faculty members.

F-3: Funding organizations should regularly evaluate, and if necessary redesign, their proposal and review criteria to make them appropriate for interdisciplinary activities.

F-4: Congress should continue to encourage federal research agencies to be sensitive to maintaining a proper balance between the goal of stimulating interdisciplinary research and the need to maintain robust disciplinary research.

Professional Societies

PS-1: Professional societies should seek opportunities to facilitate IDR at regular society meetings and through their publications and special initiatives.

Journal Editors

J-1: Journal editors should actively encourage the publication of IDR research results through various mechanisms, such as editorial-board membership and establishment of special IDR issues or sections.

Evaluation of IDR

E-1: IDR programs and projects should be evaluated in such a way that there is an appropriate balance between criteria characteristic of IDR, such as contributions to creation of an emerging field and whether they lead to practical answers to societal questions, and traditional disciplinary criteria, such as research excellence.

E-2: Interdisciplinary education and training programs should be evaluated according to criteria specifically relevant to interdisciplinary ac-

tivities, such as number and mix of general student population participation and knowledge acquisition, in addition to the usual requirements of excellence in content and presentation.

E-3: Funding organizations should enhance their proposal-review mechanisms so as to ensure appropriate breadth and depth of expertise in the review of proposals for interdisciplinary research, education, and training activities.

E-4: Comparative evaluations of research institutions, such as the National Academies' assessment of doctoral programs and activities that rank university departments, should include the contributions of interdisciplinary activities that involve more than one department (even if it involves double-counting), as well as single-department contributions.

Academic Institutional Structure

U-1: Institutions should explore alternative administrative structures and business models that facilitate IDR across traditional organizational structures.

U-2: Allocations of resources from high-level administration to interdisciplinary units, to further their formation and continued operation, should be considered in addition to resource allocations of discipline-driven departments and colleges. Such allocations should be driven by the inherent intellectual values of the research and by the promise of IDR in addressing urgent societal problems.

U-3: Recruitment practices, from recruitment of graduate students to hiring of faculty members, should be revised to include recruitment across department and college lines.

U-4: The traditional practices and norms in hiring of faculty members and in making tenure decisions should be revised to take into account more fully the values inherent in IDR activities.

U-5: Continuing social science, humanities, and information-science-based studies of the complex social and intellectual processes that make for successful IDR are needed to deepen the understanding of these processes and to enhance the prospects for the creation and management of successful programs in specific fields and local institutions.

A NOTE TO THE READER

This report addresses five primary populations, all of whom participate in interdisciplinary research (IDR): researchers and educators, undergraduate and graduate students and postdoctoral scholars, institutions, private and federal organizations that fund research and education, and professional societies.

At the risk of some repetition, the guide addresses the primary groups in separate sections because of differences in perspective, primary objectives, and responsibilities.

Organization of the Report

Prominent in the discussion in this report is an analysis of what facilitates—and what impedes—interdisciplinary research. The report is organized as follows:

- **Chapter 1** provides an "interdisciplinary vision" and describes where the research community has been and where it is going.
- **Chapter 2** provides a definition of IDR, discusses four driving forces of IDR, and explores the nature of successful interdisciplinary work.
- **Chapter 3** provides several case studies describing how interdisciplinary research is performed in industry and national laboratories. Although the major emphasis in this study is on the state of IDR in academic institutions, IDR plays important roles in industrial and government laboratories, and an understanding of the drivers for IDR in those settings can provide helpful insights in the examination of IDR in academic settings.
- **Chapter 4** describes the current working environment and challenges for individual students and academic researchers interested in IDR.
- **Chapter 5** discusses the institutional barriers to interdisciplinary education and research and discusses possible research, education, and training policies to facilitate interdisciplinary work.
- **Chapter 6** discusses the barriers that federal and private funding organizations encounter in their support of interdisciplinary education and research activities and proposes some innovative funding strategies.
- **Chapter 7** discusses the role that professional societies play in facilitating interdisciplinary education and research.
- **Chapter 8** describes the challenges of evaluating interdisciplinary research and education activities, including evaluating the direct and indirect impacts of IDR; the people who perform IDR; the institutions, centers, and programs that engage in IDR; and the issue of national comparative assessment of departments.
- **Chapter 9** examines the overall structures in which IDR takes place and proposes some incremental and transformative policies to facilitate it.

- **Chapter 10** synthesizes the committee's findings and recommendations (also presented at the end of each chapter) to provide an overarching picture of the actions that can be taken by all the populations described to facilitate interdisciplinary research and education.

Method

The work of the committee began with a review of the literature—the results of which are provided in Appendix H.

The committee also undertook a number of activities to collect additional information; these are described in several appendixes:

- **Appendix C** provides additional information on the Convocation on Facilitating Interdisciplinary Research hosted by the committee on January 29-30, 2004 in Washington, D.C. At the convocation, the committee heard the experiences and opinions of representatives from private, federal, international, and state funding organizations who have had leading roles in facilitating IDR; leading senior and junior researchers involved in IDR; interdisciplinary research-center directors; experts in interdisciplinary education and training; and more than 200 participants.

In addition, the convocation included a poster session that featured some 30 model interdisciplinary programs and opportunities for participants to provide their thoughts to the committee in written (survey) and oral form.

References to speaker presentations and convocation participant comments appear throughout the report.

- **Appendix D** provides a qualitative and quantitative historical analysis of the development of IDR and interdisciplines, university departments, and professional societies.
- **Appendix E** provides an analysis of the committee's surveys of students, postdoctoral scholars, faculty members, funders, policy makers, and disciplinary societies involved in interdisciplinary research and education. This analysis is referred to throughout the report. The surveys asked questions about the impediments, programs, and evaluation criteria related to IDR and gathered suggestions for recommendations on how to facilitate IDR.

The first survey, referred to in the report as the "convocation survey," was given to participants who attended the convocation described above; 91 convocation participants responded to the survey.

A slightly modified version of the convocation survey, called the "individual survey," was posted on the committee Web site. An invitation to participate in the survey was sent to universities, professional societies, nongovernment organizations, and participants in federal and private interdisciplinary programs; 423 people responded to the solicitation.

An invitation to participate in a third survey, called the "provost survey," was distributed on line to provosts or vice-chancellors of institutions that conduct IDR; 57 institutions responded.

- **Appendix F** provides a list of the administrators, scholars, and center directors interviewed by the committee and summarizes the thoughts they offered regarding IDR.
- **Appendix G** summarizes the statements of interdisciplinary researchers in a wide variety of research fields who participated in three focus groups at the first Keck *Futures* Conference, titled "Signals, Decisions, and Meaning in Biology, Chemistry, Physics, and Engineering," held on November 14 in Irvine, California.
- **Appendix H** provides the report bibliography.

Boxes

Throughout this report, text boxes are used to highlight activities, programs, and policies that the committee found particularly interesting and to help to illustrate its findings and recommendations. These boxes are summaries of existing literature and reports or are based on new information gathered by the committee. They are organized into seven categories:

- **Innovative Practices** highlight existing programs that are particularly innovative and that illustrate the committee's recommendations.
- **Structures and Policies** illustrate unique organizational structures and institutional policies.
- **Toolkit** provides illustrations of how proposals, individuals, funding organization programs, interdisciplinary centers, and research outcomes can be evaluated.
- **Definitions** describe and define IDR, its management, and its evaluation.
- **Evolution** shows how research, organizations, and institutions involved in IDR have changed.
- **Convocation Quotes** are snapshots of particularly revealing or insightful comments by panelists and participants of the convocation that illustrate some of the key barriers and drivers for IDR.
- **Survey Analysis** provides quantitative highlights from the committee's surveys of convocation participants and others.

Case Table

To help the reader navigate the case studies presented in the report, Table ES-1 provides a table of the boxes in the report, listed in order of appearance, by category and title. For each box, the major topics are indicated. Most boxes cover more than one topic area.

- **Driver:** These boxes illustrate the four drivers of IDR, the inherent complexity of nature (C), the drive to explore basic research at the interfaces (I), the need to solve societal problems (S), and the stimulus of generative technologies (G).
- **Industry:** These boxes show how industry plays a role in IDR.
- **National Lab:** These boxes provide examples of IDR at national labs.
- **Academe:** In these boxes, IDR in academic settings is highlighted.
- **Undergrad, Graduate, Postdoc, and Faculty:** These boxes provide examples of programs and policies to facilitate interdisciplinary work for these groups of students, researchers, and teachers.
- **Structure:** These boxes show how particular administrative and bricks and mortar structures can facilitate IDR.
- **Policy:** These boxes provide discrete examples of effective policies to promote interdisciplinary work.
- **Evaluation:** These boxes illustrate a variety of strategies for evaluating interdisciplinary people and programs.
- **Funding:** These boxes show how funding agencies have effectively facilitated IDR.
- **History:** These boxes provide a historical overview of particular interdisciplinary projects or fields.
- **Managing Collaborations:** These boxes illustrate management options for bringing together and maintaining interdisciplinary teams.
- **Professional Society:** These boxes show how professional societies have played a role fostering and facilitating IDR.

The committee hopes that this report will increase the understanding of interdisciplinary research and encourages readers to undertake actions that will help facilitate it.

TABLE ES-1 List of Boxes by Order of Appearance, by Category and Title

Box	Category	Case/Topic
1-1	Struct/Policy	Columbia Univ./ Brown Univ.
1-2	Struct/Policy	IDR in Netherlands
1-3	Struct/Policy	EURAB Report
2-2	Evolution	MIT Radiation Laboratory
2-3	Evolution	X-Ray Crystallography
2-4	Innovative Practice	KDI Institute
2-5	Evolution	Argonne Nat'l Labs Advanced Photon Source
3-1	Innovative Practice	Philips Physics Research Laboratory
3-2	Innovative Practice	Role of IDR at IBM
3-3	Innovative Practice	Hard-Disk-Drive Research
4-1	Toolkit	Summer Research Opportunities
4-2	Innovative Practice	Arizona State Univ. School of Life Sciences
4-3	Innovative Practice	Harvard Univ. Global Assessment Project
4-4	Innovative Practice	Univ. Minnesota, Institute for Mathematics and its Applications
4-5	Innovative Practice	Penn State University, Huck Institutes
4-6	Innovative Practice	Fred Hutchinson Cancer Research Center
5-1	Evolution	NRC Graduate Program Assessment
5-2	Innovative Practice	Physical Barriers to IDR
5-3	Innovative Practice	Haverford College
5-4	Innovative Practice	University of Wisconsin
5-5	Toolkit	University of Southern California
5-6	Toolkit	Univ. Illinois Urbana-Champaign, Beckman Institute
5-7	Toolkit	State University of NY, Stony Brook
5-8	Toolkit	UC Davis, Univ. Michigan
6-1	Evolution	DARPA
6-2	Innovative Practice	NASA — NAI

	Driver	Industry	National Lab	Academe	Undergrad	Graduate	Postdoc	Faculty	Structure	Policy	Evaluation	Funding	History	Managing Collaborations	Prof. Society
				X					X						
				X	X	X			X	X	X			X	
				X	X	X			X	X	X			X	
	S	X	X	X									X		
	G												X		
	G			X							X	X		X	
	G	X	X	X										X	
		X												X	
		X												X	
		X		X										X	
		X	X	X	X	X	X	X							
				X	X	X		X						X	
				X			X				X			X	
		X		X			X				X	X			
				X	X	X		X	X		X			X	
				X		X	X	X						X	
				X		X					X				
		X	X	X					X					X	
				X	X										
				X				X		X	X				
				X				X		X	X				
				X				X		X	X	X			
				X				X						X	
				X						X		X			
	S											X	X	X	
	I			X		X	X	X				X		X	

continues

TABLE ES-1 Continued

Box	Category	Case/Topic
6-3	Innovative Practice	NIH
6-4	Innovative Practice	DoD — MURI
6-5	Innovative Practice	BWF — Career Transition Awards
6-6	Evolution	Rice University
6-7	Innovative Practice	HHMI — Janelia Farm
6-8	Toolkit	OSTP
6-9	Evolution	Biomedical Engineering
7-1	Toolkit	Journals
7-2	Toolkit	Professional Societies
7-3	Innovative Practice	Assn. of American Geographers
7-4	Innovative Practice	Coalition for Bridging the Sciences
8-1	Toolkit	Harvard Interdisciplinary Studies Project
8-2	Innovative Practice	National Science Foundation Engineering Research Centers
8-3	Evolution	Hybrid Vigor Institute
8-4	Toolkit	National Science Foundation IGERT
8-5	Toolkit	Dutch Universities
8-6	Toolkit	Transdisciplinary Tobacco Use Research Centers
9-1	Definition	Matrix Management
9-2	Innovative Practice	Evergreen State College, Penn State Univ., Harvard Univ., Brown Univ.
9-3	Innovative Practice	Rockefeller University
9-4	Innovative Practice	Purdue University
9-5	Innovative Practice	Univ. Washington Program on the Environment, CMU/University Pittsburgh Center for Neural Basis of Cognition
9-6	Innovative Practice	Stanford University Bio-X
9-7	Innovative Practice	Biomedical Informatics Research Network

	Driver	Industry	National Lab	Academe	Undergrad	Graduate	Postdoc	Faculty	Structure	Policy	Evaluation	Funding	History	Managing Collaborations	Prof. Society
	I					X	X	X				X		X	
	S			X		X	X	X				X		X	
	I						X	X				X		X	
	G			X					X				X		
	I								X			X		X	
									X	X		X			
	I			X							X	X		X	X
														X	X
								X	X		X	X		X	X
		X		X				X	X		X		X	X	X
												X		X	X
				X				X			X				
	I	X		X					X	X	X	X		X	
				X		X	X	X	X		X			X	
	I			X		X	X			X	X	X		X	
				X							X				
				X							X			X	
				X					X	X				X	
				X	X					X					
				X					X	X			X	X	
	I			X					X	X		X			
				X					X	X	X			X	
	I			X					X	X				X	
	G			X					X		X			X	