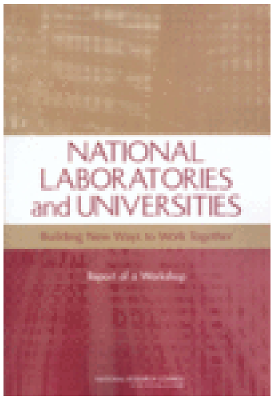

National Laboratories and Universities: Building New Ways to Work Together -- Report of a Workshop

Committee on National Laboratories and Universities, National Research Council

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NATIONAL LABORATORIES and UNIVERSITIES

Building New Ways to Work Together

Report of a Workshop

Committee on National Laboratories and Universities

Policy and Global Affairs

National Materials Advisory Board

Board on Manufacturing and Engineering Design

Division on Engineering and Physical Sciences

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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 quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. The review of this report was overseen by Alan Schriesheim, Argonne National Laboratory, who was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

Federal laboratories and the Department of Energy's (DOE) nine contractor-managed, multiprogram national laboratories, in particular, have a long history of productive collaboration with universities. Traditional collaborative mechanisms have included joint proposals and programs, personnel exchanges, and utilization of laboratory facilities by university researchers. Several national laboratories are managed by universities, while others are managed by partnership organizations with university participation. Many have evolved close links with one or more universities in a range of research areas, often due to geographical proximity. The laboratories play a strong role in education, providing training and research opportunities for students through DOE and other funding sources.

During the 1990s, the role of the national laboratories in the nation's post-Cold War science and engineering enterprise was scrutinized and reexamined, most notably by a task force chaired by former Motorola Chief Executive Officer (CEO), Robert Galvin. While a consensus emerged that the labs should continue to focus on their core missions, several initiatives were launched to link research at the labs more closely to commercial activity, such as expanded utilization of Cooperative Research and Development Agreements.

Today, several of the laboratories are reexamining their relationships with universities and developing new approaches to collaboration. One example is the joint research institutes, in partnership with the University of Washington and the University of Maryland, launched by Pacific Northwest National Laboratory. These institutes, housed at the universities, provide a number of benefits for each party. However, new approaches to collaboration between the national laboratories and universities bring with them a number of challenges. Included among them are cultural and management differences, as well as differences in procurement rules, human resource policies, and intellectual property policies, which can complicate the process of setting up and running joint research centers.

Numerous workshops and reports by the National Academies and other groups have examined research collaboration between industry and universities. The technology transfer activities of government laboratories have also been studied extensively. However, national laboratory-university ties have not been reviewed from a national perspective.

On July 10-11, 2003, the National Academies held a workshop in Berkeley, California to address best practices and remaining challenges with respect to national laboratory-university collaborations. Managers, scientists, engineers, and other experts in the field were invited to exchange views on how to structure university-laboratory collaborations in order to maximize benefits to their institutions and the U.S. research enterprise. The workshop covered a wide range of collaborative practices, from individual investigator-level collaborations; to joint centers; to laboratory-run, university-populated user facilities. The report that follows is a summary of the views expressed in that workshop.

Jerome Grossman
Chair

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Introduction

The Department of Energy (DOE) national laboratory system was created in the early postwar environment of the 1950s. These research institutions are focused on meeting major mission needs in the areas of national defense, energy, environment, and basic science. Since their inception, the DOE laboratories have had a strong history of productive collaboration with universities at a variety of levels. The Lawrence Berkeley National Laboratory, established in 1931, was one of the early examples of strategic laboratory-university collaboration, one that continues today with strong interaction between the laboratory and University of California researchers. The working model for this laboratory, which is managed and operated by the University of California, was based on a belief that scientific research is best done by teams of individuals with different fields of expertise working together. Many participants at this workshop acknowledged that the interdisciplinary team approach continues to be one of the hallmarks of the national laboratories today. Over the last decades, thousands of collaborative activities between the laboratories and the universities have been established, ranging from personnel exchanges, to productive research collaborations among individual investigators, to joint research programs formed around major scientific user facilities, to strategic institutes that have been established to examine new areas of scientific endeavor (nanotechnology, systems biology and global change, to name a few).

This workshop was designed to explore the current state of collaboration between the national laboratories and universities and to examine new models for collaboration that can provide increased value to both parties through strategic institutional alliances. More than 65 participants from national laboratories, universities, and government agencies took part in an open dialogue on the benefits of and barriers to collaborative research activities between the national laboratories and universities at the July 2003 workshop. Although the focus was on the interactions between DOE laboratories and universities, information on collaborations in other agencies (National Institute of Standards and Technology [NIST] and Department of Defense [DOD]) and on the growing needs of new agencies such as the Department of Homeland Security (DHS) was provided to bring a broader base of examples and drivers into the dialogue. A number of workshop participants were particularly interested in understanding the experiences across research institutions and identifying best practices that might be employed in developing or enhancing collaborations going forward. The four topical areas listed below were covered in depth, both in presentations and in breakout discussion sessions held on the second day of the workshop:

1. Institutional incentives and structures
2. Scientific user facilities
3. Building the science and engineering workforce
4. Conducting research in a classified environment

Key barriers to collaboration that have to be addressed were also identified to ensure that future collaborative research programs can take advantage of the best that both the laboratories and the universities have to offer the nation in addressing major national challenges. A summary of the major points of these discussions is presented later in this report.

The workshop began with a session entitled "We All Agree Collaboration Is a Good Thing—So How Can It Be Strengthened?" The presentations and discussions that followed articulated some of the dimensions of this long-term challenge:

- Both university and national laboratory researchers were able to articulate the value of collaboration for individual participants and for the national research fabric, emphasizing the distinctions in "flavor" or character of research resources available to universities versus those available to the laboratories.
- Numerous types of collaboration were discussed, exemplifying the many attempts made by universities and laboratories to work together over a period of decades. These ranged immensely in scale and complexity, from single collaborations between principal investigators (PIs) to multi-tiered formalized arrangements between partner institutions.
- The various attempts were inevitably viewed as scientifically successful but faced with structural, administrative, and cultural challenges

that required institutional change. Even simple PI-to-PI research agreements were held up as examples of difficult contractual transactions.

- Workshop presentations revealed that the institutional changes required to facilitate collaboration were sometimes at the agency level, as demonstrated by differences in agency-wide collaborative practices presented by DOD and NIST relative to DOE. They were sometimes at the level of the individual institution, as demonstrated by the widely varying degrees of institution-by-institution concern regarding specific expense categories (travel support, conference support, academic center support, and support of joint appointments). Sometimes, however, they were purely cultural, as in the different values accorded to "team science" versus individual contributions.

Piecemeal sharing of best practices appears to have occurred to some degree (e.g., transfer of the Los Alamos Oppenheimer fellows concept to Lawrence Livermore National Laboratory), but no evidence was presented of a systematic effort to share best practices throughout the laboratory and university systems. It is hoped that this volume represents a successful first attempt.

Importance of Collaboration

Workshop participants pointed to a number of reasons for collaboration between universities and national laboratories. Laboratories have an extensive investment by the federal government in facilities, equipment, and staff. This is very attractive for university researchers, who may not have access to major scientific facilities or to teams of researchers working on particular application areas. Another benefit of collaborative research is the broader problem set available to university researchers working with national laboratory teams. The laboratories were viewed by many as having a strong connection to real problems (the mission-oriented link) and yet still being close enough to academic research disciplines to have the ability to transfer their understanding to university situations. Laboratory staffs see universities as able to conduct research in a less constrained environment, driven less by mission and more by intellectual curiosity, enhancing their scientific productivity through the use of graduate students.

Several presenters from the laboratories reinforced the importance of university-laboratory collaborations. From the laboratory point of view, university collaborations at all levels are important to delivering world-class research and strengthening the overall contribution of the laboratories to the nation's research enterprise. In addition, the interaction with university researchers increases the quality and impact of the user facilities and helps to improve them. Finally, the opportunities to enhance the contributions of the laboratory to science education in the United States and to obtain access to top-level recruits were seen as additional benefits for the laboratory. Benefits to the universities include access to the world-class user facilities and capabilities at the laboratories, and the potential for increasing the number of graduates from universities in critical science and technology (S&T) skills areas.

There are several forms of collaborative activity relative to the breadth of capabilities available at the national laboratories, particularly those with major user facilities. These were described by many of the presenters and include university faculty or students using a facility, joint research programs, joint educational programs, and at the highest institutional level, management contracts. Although each of these modes of interaction brings a number of benefits to both parties, most participants clearly identified the user facilities at DOE laboratories as one of the most important assets for the scientific community.

In the post-Cold War era, the DOE Office of Science (DOE-SC) national laboratories have become the major stewards of large-scale science capabilities that serve the entire U.S. scientific community. This stewardship function has grown rapidly together with advances in science and technology and is a significant role for DOE-SC. According to John Marburger, director of the Office of Science and Technology Policy (OSTP), the office spends approximately 40 percent on average of its programmatic funds on facilities operations. Additional funds are devoted to construction of new facilities. The rationale for continued federal investment in the laboratories is to ensure that these capabilities remain available to the U.S. scientific community.[1]

BENEFITS OF COLLABORATIONS TO UNIVERSITIES

The scientific facilities at the national laboratories and the unique instrumentation they provide are increasingly essential for university research groups to carry out their advanced scientific experiments in support of a broad set of science agendas. Some of the important benefits to universities from collaborations with national laboratories are noted below, taken largely from discussions at the Incentives and Structures breakout session at the workshop:

- **Science requiring large, complex facilities.** Universities generally operate through principal investigators and small groups who are not in a financial position to support large facilities such as the Advanced Photon Source at Argonne National Laboratory (ANL) and the teams of trained scientists and technicians required for effective and safe operation. Even if a university were in a position to fund a major laboratory, support for

[1]This section draws heavily on remarks presented by Michael Holland on behalf of John Marburger at the workshop.

operations within the university environment can be problematic. Most universities count on student labor in their labs, many of whom would not have the training required to operate some of these unique, multiuser facilities. Also, there is a lack of financial and career support for the technical staff at many universities, where the career ladder is focused principally around the teaching and research staff.

- **Science requiring substantial engineering and instrument development.** Science requiring substantial engineering projects (e.g., design of instrumentation or devices that allow new discoveries to be made) cannot generally be done in the university environment because such projects are not considered "thesis material" and because the appropriately trained engineering staffs are practically nonexistent.
- **Science requiring specialized, smaller facilities that are costly to maintain.** As an example, this might include the Combustion Research Facility at Sandia National Laboratories (SNL) or the High Temperature Materials Laboratory at Oak Ridge National Laboratory (ORNL). In general, it is difficult for universities to provide service contracts for equipment, since such costs are not allowed in grant proposals, or to hire and maintain the trained staff required to operate the equipment and maintain the facility. Furthermore, the "major research instrumentation" grants for which faculty can apply are generally limited to less than $2 million, leaving a wide range of technical devices and system capabilities that fall between the <$2 million university-based equipment options and the $100 million-$500 million required for a major national user facility. The national laboratories provide this intermediate ground of capabilities.
- **Expanded opportunities for interdisciplinary research, professional development and training.** Participants in the Incentives and Structures breakout session pointed to the difficulty for universities of building interdisciplinary teams within a single principal investigator reward system and the value of the laboratories in providing these opportunities for faculty and students. The laboratories also provide important opportunities for advanced training and continuing education of science and engineering (S&E) students and faculty through the opportunity to utilize specialized equipment or to be a part of a large, scientific team effort.

BENEFITS OF COLLABORATIONS TO LABORATORIES

The national laboratories are engaged in mission-oriented research that requires a broad range of scientific and engineering disciplines. Several presentations at the workshop described how the ability to integrate professors and their students into a research project extends the capability of a laboratory team and also provides a testing ground for attracting new staff. Collaboration with universities was also described as providing a number of ancillary benefits to the laboratories (listed below), including a constituency for support of the continued mission of the laboratories and their functions.

- **Extension of capabilities to address key research questions.** Universities may have key capabilities and research facilities that are complementary to those of the national laboratories. National Science Foundation (NSF) funded centers or manufacturing-focused research centers are two examples. Collaborations between these institutions can open up entire new areas of science. This is illustrated by the experiences in the area of biology research, where we are now able to bring the tools of physics and chemistry to the life sciences in general and medical research specifically.
- **Conduct of peer-reviewed research outside the classified realm.** For scientists working in classified areas, collaboration with university programs and researchers provides opportunities to expand their career opportunities and strengthen their science through the conduct of peer-reviewed, open literature research. This independent verification of science results and the cross-fertilization of fundamental concepts between these worlds are important for researchers in the national laboratories and provide benefits to the broader scientific community.
- **Access to a diverse group of students.** The primary mission of the universities is education. Laboratories have the opportunity to expand and diversify their workforce by integrating students into their research programs. This also provides the laboratories with an important recruiting opportunity.
- **Political support for the continued missions and operations of the laboratory.** Collaboration and cooperation with universities constitute an important means for increasing political support for the laboratories. Universities need the facilities at the national laboratories to succeed in their missions and have been very vocal in their support for the user facilities. For example, of the 176 letters supporting increased FY 2004 budget requests for physical science, including the DOE Office of Science, 64 percent received were from university faculty or students.[2] University leaders are extremely influential on the political scene and are an important advocacy group for supporting the mission of the laboratories.

Most participants in the workshop reinforced the importance and benefits of a variety of research collaborations between universities and national laboratories. Of particular interest is access to the scientific user facilities at the laboratories. In addition, DOE remains the primary fund-

[2]Excerpted from Marburger's prepared remarks.

ing agency for physical science research; a significant fraction of the nation's expertise in areas such as neutron scattering, accelerator physics, and nuclear science resides within the national laboratories.[3] Yet DOE has had some difficulty enlarging its research budget to accommodate growth.

Some participants expressed concern that the lack of a clearly articulated DOE mission has contributed to the lack of political support for national laboratories, and this lack of support will present a significant challenge for future collaborative activities. The fact that both the National Institutes of Health (NIH) and NSF continue to have growing support for both facilities and research programs is viewed by some in the university systems as making it more difficult to develop, implement, and sustain collaborative research partnerships with the national laboratories. Nonetheless, the importance of finding ways to continue to build and maintain these relationships, particularly access to user facilities at the national laboratories, was viewed by most at this workshop as critical to their future endeavors. In fact, Marburger's comments, delivered by Michael Holland from OSTP, reinforced this point, stating that the laboratories are "helping the universities carry out their research mission for all of the science agencies."

While most agreed that these partnerships were important, they also agreed that there were a number of challenges to making these relationships work, even at the individual investigator level. These challenges, although not necessarily unique to collaborations between universities and national laboratories, nevertheless were viewed as important to deal with in order to increase the opportunity for successful collaborations. As noted by the title of the plenary session, if collaboration is such a good thing, why isn't there more of it?

Prepared remarks from key individuals were presented in four major areas of concern, followed by breakout sessions on each of these topics:

1. Incentives and structures
2. Access to major user facilities
3. Building the S&E workforce of tomorrow
4. Collaboration in the context of classified research

The following material represents the key items of discussion and major ideas presented during both the formal sessions and the breakout group discussions. Many of these same ideas are presented again in Appendix E, where they are grouped by types of collaboration.

[3]Excerpted from Marburger's prepared remarks presented by Michael Holland entitled, "On National Laboratory-University Collaborations."

Incentives and Structures

There are several scales of interaction between national laboratories and universities, from the investigator scale, to new models around joint institutes, to user facilities, and at the highest level, laboratory management. Each of these interactions is based on different incentives and faces structural barriers to collaboration that must be considered. In addition to the scale of interaction, the differences between the expectations, missions, and institutional structures of the laboratories and universities must be understood and then addressed to enhance the ability to engage in more effective collaborative activity, particularly at the institutional scale. Strategic partnering at multiple levels across institutions provides a formula for success. This session of the workshop focused on understanding the issues relative to different incentives and institutional structures that can provide barriers to collaboration between the laboratories and the universities and on identifying some potential paths to solution.

While the incentives for collaboration were seen by many participants as differing across scales, most participants voiced the importance of these collaborations for meeting their mission and research goals. At the individual investigator level, collaborations are developed to support key proposals or to meet specific capabilities needed for research programs. According to Gerald Stokes, director of the Joint Global Change Research Institute, some DOE programs encourage the participation of university researchers as a competitive factor in some solicitations. At the very highest levels, institution to institution, strategic interaction with universities in targeted areas is viewed by some laboratories as critical to their goals for innovation. Alton Romig, of Sandia National Laboratories, spoke to the strategic focus at Sandia relative to building collaborations with universities, with an emphasis on select university programs that support laboratory priorities, such as the Nanoscale Science and Engineering Center or the research area of microelectronics. This view was echoed by Jeffrey Wadsworth from Oak Ridge National Laboratory, who described a set of partnership activities between ORNL and targeted universities that is helping to build collaborative research programs and new joint institutes and to strengthen their staff capabilities and recruiting at the laboratory.

The importance of relationships at higher levels between the institutions was reinforced by presenters and some participants. At Oak Ridge, for example, Wadsworth pointed to the key role that Georgia Tech played in ORNL's successful proposal for a nanoscale science research center. Stokes described the model for joint institutes, an emerging concept for collaboration, as an option for developing a strategic collaboration between a university and a laboratory at the institutional level. Yet at all levels, significant issues or challenges were identified that create disincentives for collaboration. These fall into three general areas:

1. Institutional structures, including contractual mechanisms;
2. Financing models and resource availability; and
3. Research models and expectations.

Key points raised by participants in the workshop in each of these areas are described below.

INSTITUTIONAL STRUCTURES

Institutional structures are optimized for each type of institution and there are differences among them. These differences present challenges for collaborative activity between institutions. The way in which each institution handles contracting, for example, is driven in part by its overall mission, its work culture, and the regulations under which it must operate. Contractual mechanisms were identified by many participants as extremely problematic. The breakout session identified at least three layers of regulations for the laboratories: (1) those stemming from DOE (which in itself is historically a composite of several agencies), (2) those stemming from practices in DOE field offices, and (3) those mandated by the contractor institutions running the laboratories. On the university side, the accounting and contract or grant language is dictated largely by federal Office of Management and Budget (OMB) circulars.

As a result of their different historical and sectoral origins, contractual language requirements of national labs and universities were often simply incompatible. For example, a laboratory might require an indemnification clause in all of its contractual agreements, yet state-run universities are expressly prohibited from signing an indemnification clause. Different accounting and audit requirements between the two types of institutions can also drive bizarre behaviors. For example, the apparent "cost of a person" difference between universities and national labs can motivate labs to offload people onto universities, while providing the same nominal salary. These same differences in accounting procedures can make it extremely difficult for contractor-run laboratories to make joint faculty appointments with universities.

Many participants in the breakout session echoed the challenges in the current system, where project funding must generally be obtained for collaborations either through a subcontracting mechanism or by both institutions submitting proposals to different funding agencies. The problem with the first model is that it does not represent the equal partnership that many collaborators would prefer to see. The "work for hire" framework used by most laboratories to secure research collaborations was mentioned as being fundamentally antithetical to collaboration between equals. The problem with the second model, two separate proposals, is that one party may succeed in obtaining funding through the proposal process, and the other may not, resulting in no collaborative program. Several participants also raised the point that there is some inconsistency within DOE in the way collaborations are funded—each part of DOE works a bit differently. The models being used by NIH were raised as good examples to look at for thinking about university-laboratory collaborations. The NIH glue grant was raised as a specific example.[1] Several university representatives stated that NSF does not have a good model for these collaborative arrangements, and given the importance of NSF to university researchers, having such an option at least within a portion of the NSF research budget would be helpful. Most participants voiced the view that a separate source of funding specifically targeted at collaborations would help significantly to address this broader issue.

The problem in sharing human and financial resources between laboratories and universities was attributed to the differences between DOE procurement regulations and the OMB circulars under which universities operate. Research administrators in attendance suggested that an OMB-

[1]The purpose of the NIH Glue Grant Initiative is to make resources available for currently funded scientists to form research teams to tackle complex problems that are of central importance to biomedical science and to the mission of the National Institute of General Medical Sciences (NIGMS), but that are beyond the means of any one research group. A high level of resources may be requested to allow participating investigators to form a consortium to address the research problem in a comprehensive and highly integrated fashion. For more information on glue grants, please visit http://www.nigms.nih.gov/funding/collab.html.

blessed universal agreement for university-laboratory collaborations or a reworking of the original OMB circulars would be a potential solution.[2]

The differences in contracting processes and priorities, time to move paperwork through systems, and accounting challenges make collaboration difficult. The bottom line is that collaborative programs require extra effort to address these structural differences between the organizations. Participants suggested that we need either the resources required to run this gauntlet or the opportunity through specific funding sources at the national level to compete for programs that would require and support a collaborative university-laboratory team (see discussion on finances below).

Another institutional challenge is presented by joint appointments. Particularly for the joint institute construct, the ability to provide joint appointments for researchers at both the university and the laboratory is important to achieving the desired goals of the collaboration. Several participants voiced the opinion that joint appointments are extremely beneficial to collaborative research, but they can be extremely difficult to achieve. At a nonuniversity-managed laboratory, real joint appointments are much easier to establish since the individual actually does have a single employer. At nonuniversity-managed laboratories however, joint appointments are much more difficult, if not impossible, to achieve. The problem seems to lie in the two different human resource systems and overhead systems that can operate in universities and national laboratories. It really seems necessary to have high-level formal commitments with universities, not only for joint hiring, but also to enable more collaborative programs and joint institutes, for example. These joint research centers were mentioned several times as a worthwhile method of establishing joint collaborative programs.

Finally, the issue of foreign nationals working on DOE-funded projects or at DOE sites was raised by both university and laboratory participants. This issue was also addressed in several of the other sessions. A significant proportion of the student body in science and engineering today consists of foreign students. Universities have difficulty accepting contracts or research opportunities that restrict foreign students from participation. Yet DOE laboratory funding increasingly carries some restrictions on participation, requiring U.S. citizenship in many cases to either work on the project and/or to visit the government facility for meetings, and so forth. Some universities simply will not take on projects that may restrict student participation. Although both laboratory and university participants discussed how they have addressed this issue in the past, it is clear that a widespread understanding of these options was not held by all partici-

[2]This section draws heavily on comments made by Joyce Freedman, workshop participant.

pants and that it would be useful to develop a set of recommended procedures for facilitating broader student participation in DOE (and now DHS, as well) research programs.

FINANCING MODELS AND RESOURCE AVAILABILITY

Participants raised a number of issues relative to finances and the availability of resources for supporting collaborative activity, some of which were viewed as providing major barriers to collaboration. A major issue is the difference between the two institutions in overhead rates. Laboratories must fully recover their costs on a project, and their staff has relatively high overhead rates compared to those at a university. For groups wanting to develop a joint research project, this has led to some bizarre workarounds, such as putting some of the research team on the other institution's payroll to reduce the nominal overhead rates.

Another point raised is that there is no source of research funds specifically designed to support joint activities. LDRD (laboratory-directed research and development—a type of overhead-generated funding with fewer use restrictions than programmatic funding) money was used to sponsor many collaborations with universities, but that pot is shrinking greatly. The current situation, in which small amounts of money are drawn from many different types of sources within the laboratory, leads to erratic support of collaborative programs and graduate students, which is particularly damaging to the latter. In addition, the different sources of money usually have different criteria for use and rules of accounting, which can hamper their intended purpose.[3] For example, an issue raised by Alvin Kwiram at the breakout session is that at some laboratories, seminar money cannot be used to support foreign attendees or speakers, yet many university researchers and U.S. scientists are not U.S. citizens. Some laboratories additionally lack a category of funding that would allow them to be members of university consortia.

In terms of external, programmatic funding, breakout session participants expressed the view that the situation was not much better. Each institution and/or research team ends up competing for the same pot of money, and one of these groups must be in a "lead" position. This lack of joint money leads to distortion of the peer relationship between lab and university researchers. Not only does this situation create the need for subcontracting agreements between institutions (leading right back to the contractual difficulties and different rate structures), but it also sets up a

[3]This section draws heavily on remarks made by Jeffrey Wadsworth on "Strengthening Collaborations: ORNL's Experience" at the workshop.

"rich-uncle, poor-nephew" phenomenon, where the lead organization controls the funding, scope, and direction of the research and the "supporting" organization is in a position simply of support. The Accelerated Strategic Computing Initiative (ASCI) program seems to be a good example of a program in which the funding is shared between laboratories and universities. Participants were intrigued by the possibility of extending this model to other programmatic sources of funding.

RESEARCH MODELS AND EXPECTATIONS

The primary mission of a university is the creation and dissemination of knowledge; the primary mission of a national laboratory is providing results that support DOE's research program. These differences in focus result in differences in the way in which the accompanying research is conducted. Universities have the ability to bring a significant number of graduate and undergraduate students to a project. However this can lead to different time scales for the expectation of project results, as well as different working models for conducting research. A doctoral student may need 4-5 years on a project to complete both research and educational activities. Master's students may need a clearly defined 1-year project to complete the thesis requirement. Laboratory projects may have more of a 1-2 year time frame for completion, with continuous progress expected and reported on to DOE. Additionally, the large, complex nature of many laboratory projects requires them to be team driven, whereas most universities reward individual (single PI) achievements.

Access to Major User Facilities

User facilities at DOE laboratories range from large, international facilities such as the Advanced Photon Source at ANL, to smaller, single-purpose facilities such as the Combustion Research Facility at Sandia. The stewardship function for these unique capabilities and advanced scientific facilities has grown rapidly over the last decades and is now a dominant role of the laboratories. Approximately 20-35 percent of the budgets of four of the multiprogram laboratories (Argonne, Berkeley, Brookhaven and Oak Ridge) were spent on facility operations and construction in FY 2002.[1] Facilities at the labs are viewed as extremely important resources for academics, often providing opportunities to conduct key scientific experiments that cannot be conducted anywhere else.

There is also a wide range of users, described by William McLean from Sandia National Laboratories, John Gibson from Argonne National Laboratory, Takeshi Egami from the University of Tennessee, and others. Users range from visiting university scientists and engineers, to industry researchers, to students (both undergraduate and graduate levels) and postdoctoral researchers. Users are attracted to the unique facilities and capabilities at the laboratory and the high-quality operational support provided there, as well as the opportunity to work with world-class staff. The process for gaining access to these facilities varies by facility, by funding opportunity, and by scientific team.

Several presenters described the collaborative management approach

[1]Michael Holland drawing on Marburger's prepared remarks.

employed at select user facilities to ensure the involvement of users in planning the activities of the facilities and the scientific projects to be implemented there. From Egami's perspective as a user, he felt that academics were deeply involved in the planning, construction, and operation of facilities and that university-laboratory collaborations are strong and will continue to grow. Nonetheless, participants in this session acknowledged that there are challenges to effective collaboration, some of which were discussed in the dialogue on incentives and structures, and some of which are more specific to the facility access requirements. Primary issues identified by participants included contractual issues, funding, and increasing concern about access to these facilities by foreign nationals. Each of these is discussed in more detail below.

CONTRACTUAL AND PLANNING ISSUES

Contractual issues were raised by a number of participants in the User Facilities breakout session as a barrier to collaboration. Although many of the challenges echoed the perspectives raised in the Incentives and Structures session, this group also raised the problem of negotiating specific access to user facilities on a case-by-case basis, where no universal standard or master agreement exists that would facilitate collaborative work. Administrative arrangements are on a case-by-case basis, and often inconsistent from institution to institution. The need was expressed by most participants for standardized MOUs (memorandum of understanding) between universities and user facilities. Intellectual property terms, in particular, varied across institutions, were very complex, and were viewed by many as one reason for the increased difficulty in creating collaborative arrangements (see discussion in Incentives and Structures).

In addition, the need for an agreement at the funding agency level was identified as important to successful interactions. Differences in agency guidelines for working with DOE user facilities lead to differential access for grantees funded by different sources. Egami referred to the agreement between DOE and NIH for use of beamlines, for example, which has provided positive support to lab-university collaboration. In NSF, on the other hand, there is a process that requires beamtime to be approved as a precondition for funding, leading to a "chicken-and-egg" problem.

Relative to planning the direction and course of the facility itself, some concern was raised that input from the scientific community is well established for large facilities but smaller facilities don't benefit from the same level of interaction and support.

Additional concerns were raised relative to a perceived decline in the scientific orientation of the facilities, driven perhaps by the general reduction in DOE support for science. Holland pointed out that whereas large facilities have well articulated missions that are easily understood by Congress, smaller facilities have no such articulated mission and have more difficulty garnering support.

FUNDING SOURCES

The funding issue was raised as part of the larger overall concern that funding for basic science in general is declining, and particularly for the physical sciences. Ever more expensive large facilities will require new, creative financing models that have yet to be determined. In the context of user facilities and collaborative research, the availability of resources was definitely seen by many as an issue. Users consistently mentioned travel funds as problematic. University investigators wanted travel funds so that they could use the beamlines as the scientific needs become apparent in their research. This was not something they felt they were likely to know about 3 years in advance, when the original research proposal was written and requests for travel funds could be incorporated more easily. Expressly allowing supplemental funding requests to DOE grants would more easily allow PIs to travel to user facilities and conduct the necessary research in an appropriate time frame to support their work. In this case, NSF was raised as an example of an agency that more readily supports these incremental requests.

From the perspective of DOE lab researchers, several participants stated that they had similar difficulties in obtaining travel funding, even for their own principal investigators on a project. However, the laboratories' flexibility in addressing travel funding requests varied and appeared to improve with the laboratory's access to non-DOE (e.g., contractor origin) funding sources. One researcher indicated that the problems he encountered at Sandia were "not serious."

A resolution of the travel funding issue was not easily forthcoming. One expressed barrier was the national laboratory researchers' fear that DOE money spent in travel would be taken from the technical staff at the laboratory and further drain support from the user facility itself. The example of user facilities in Europe was raised by Gibson as a potential model for generating travel funding support. There, he noted, large user facilities routinely provide travel grants as part of their operating budgets, comprising approximately 1 percent of the cost of operating the facility. However, not all workshop participants agreed this model would solve the dilemma. The allocation of travel funds at the agency level could well be less personally painful to laboratory researchers, relieving them of the necessity of making individual tradeoff decisions. Yet, opponents of travel funding support felt that, in the context of a fixed, overall budget, the outcome was sure to be the same: a guaranteed budget for travel funding would limit the amounts that could be spent on other laboratory needs. Even the 1 percent figure cited for the European approach represented a significant incursion into laboratory operational needs. The potential solution of an expanded DOE budget that could accommodate all needs, including essential travel needs, was not considered realistic by parties on either side of the discourse.

ACCESS BY FOREIGN NATIONALS

Increased attention to security since 9/11 has presented some new challenges for collaborative research. Foreign-born or non-U.S. citizens represent an important fraction of the scientific community and an increasing fraction of graduate students in science and engineering.[2] An increasing focus on security and preapprovals for foreign nationals has made it more difficult for non-U.S. citizens to have access to user facilities. Not only is there increased paperwork, but delays in obtaining visas can prevent foreign researchers from getting to the facility when their access date arrives. Given that many of these facilities, particularly the beamlines, are generally oversubscribed, finding alternative access times consistent with the time lines for the research under way can be a major challenge. A related concern was that the current U.S. political position, reinforced by limiting access at these U.S. facilities, will result in reciprocal action and exclusion of U.S. researchers from state-of-the-art foreign facilities.

Although there are certainly differences among facilities, McClean put forward a suggested list of best practices that could help address some of the challenges mentioned above. Finding ways to ensure collaborative research at user facilities is important, because as Gibson points out, "Partner users not only do great science, but they leave the facility better for the general user."

SUGGESTED BEST PRACTICES FOR SMALLER USER FACILITIES

- Envision collaborations at the proposal stage, and be flexible in your approach.
- Engage graduate students, and ensure that they are in residence for some portion of their thesis research related to facility use.
- Ensure capable and committed support staff at the facility, as well as a well-staffed user office.

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[2]Laura Gilliom, citing data from the American Institute for Physics, in the workshop presentation on "Strategic Relationships: Attracting Future Technical Leaders."

- Provide support to foreign national users and help them with various requirements for access to the facility.
- Implement joint postdoctoral appointments when possible.
- Use laboratory staff as adjunct faculty.
- Increase collaborations with industry where appropriate.
- Exploit advanced information technologies to take advantage of virtual links and true "collaboratories."

Building the S&E Workforce of Tomorrow

The importance of collaborations in helping build the science and engineering workforce, particularly in key, high-demand skills areas, was raised by a number of participants. Many participants pointed to the current imbalance between the laboratory need for U.S. citizens and the university production of new domestic scientists in key areas of science and engineering. From the laboratory standpoint, it is increasingly difficult to find the trained personnel needed to conduct its research missions. The university output of physical sciences Ph.D.s has an increasing number of non-U.S. citizens (more than 50 percent), many of whom are thus ineligible for employment at a national laboratory. There are critical workforce shortages in special areas of science and engineering, including nuclear engineering and radiochemistry. Some of these are documented in the Chiles and Hamre commissions' reports.[1] Programs across various funding agencies to support the development of new graduates are often not coordinated, and the time scales of support are not consistent with students' "time to degree." In addition, laboratories require a number of staff who have scientific and technical training for jobs to operate equipment at

[1]An extensive discussion is available in the report of the Chiles Commission (H. G. Chiles, et al., Report of the Commission on Maintaining U.S. Nuclear Weapons Expertise, Washington DC, 1 March 1999). The specific work force impacts of recent security measures are discussed in the report of the Commission on Science and Security chaired by former Deputy Secretary of Defense John Hamre (Center for Strategic and International Studies, Science and Security in the 21st Century: A Report to the Secretary of Energy on the Department of Energy Laboratories, Washington, DC: CSIS, April 2002).

user facilities, for example, that do not require a Ph.D., yet universities are focused on developing the academic Ph.D. candidate. It is unclear what development path will provide that technical segment of the workforce.[2]

For a prospective employee, the increased scrutiny by the laboratories and government funding agencies of foreign nationals specifically, but even of non-native-born U.S. citizens, makes the laboratories an undesirable place to work, even with their great science facilities. The case of Wen-Ho Lee has been well publicized, and many participants stated that this situation has detracted from the perception of the labs as a great place to come and do leading-edge science. The point raised by Jill Trewhella from Los Alamos National Laboratory (LANL) was that since all of the successfully prosecuted spy cases have involved U.S. or British citizens, the foreign-born wonder, "Why am I being unfairly targeted?"

In terms of workforce development, Alexander King from Purdue University presented a model that described the challenges of developing science and engineering talent, and four key mechanisms of collaboration that he believes are effective in enhancing that talent. These include (1) research projects (first and foremost), (2) equipment support (the user facility access), (3) lab staff as adjunct faculty (actually working with students), and (4) advisory committee service. He also made the point that proximity matters, leading to strategic thinking about where collaborative arrangements between labs and universities might be more successful. As Charles Shank from Lawrence Berkeley National Laboratory (LBL) pointed out, the long-time relationship and geographic proximity between LBL and the University of California have led to very productive collaborative programs.

Several laboratories have implemented fellowship programs that have been very successful in attracting talent to them. The Oppenheimer and Lawrence Livermore National Laboratory (LLNL) fellowships, for example, provide an avenue for recruiting and retaining the best and the brightest scientists, even non-U.S. citizens,

and can be coupled with extended-term appointments that provide support and continuous-term employment as the fellows obtain their citizenship. All of the laboratories have cooperative (semester-long student employment) programs and other opportunities for students that were mentioned as being helpful to laboratory recruiting efforts. The challenge of increasing the number of women and minorities in science and engineering was raised as an important issue by many participants, but they also stated that for the most part, this is a broad national issue, and not

[2]This section draws heavily on remarks made by Jeffrey Wadsworth on "Strengthening Collaborations: ORNL's Experience" at the workshop.

necessarily the responsibility of DOE alone to address. Nonetheless, all of the laboratories represented at the workshop did have some kind of program targeted to women and minority groups, as well as reaching out to specific disciplines in various science and engineering fields.

Most participants agreed that the best collaborations to support the development of S&E talent are those that reflect the primary missions of the partnering institutions.

Collaboration in National Security and Classified Research

The growing importance of national security issues and the scientific challenges to be addressed in this arena were raised as an important but potentially problematic area of collaborative research by several participants at the workshop. In addressing this topic, the first point made by presenters, echoed by many participants in the breakout sessions, is the importance of understanding the difference between national security research and classified research. Researchers are in general prohibited from working on classified research while in university facilities. However a significant portion of research relevant to national security challenges is actually unclassified and provides some opportunity for collaborative research. Trewhella pointed out the importance of idea sharing and peer review, embedded in unclassified research, in helping to maintain high-quality research activities in the classified arena. Unclassified research has significant inherent quality controls, demanded first because of the peer-reviewed competition required to obtain a grant and then because of the added review requirements to actually publish the research results. This same quality of science is highly desirable in classified work, but the same open mechanisms for ensuring quality cannot be implemented because of the closed nature of the work. Thus, to maintain the highest quality of research in a classified environment, researchers who operate in a classified world must be allowed to compete and be peer-reviewed in an unclassified environment, where their fundamental concepts, ideas, and approaches can be vetted by the community of scientists, before these ideas are brought to the classified world. Competitive, peer-reviewed, unclassified research in basic science provides an important quality check for classified work and also provides a more attractive career opportunity for scientists who are interested in the problems and programs of the classified world.[1]

David Mao from the Carnegie Institute of Washington described a specific set of projects in high-pressure physics and chemistry that demonstrated the power of this leverage between the classified and unclassified areas in basic sciences. His experience here has been that although universities do not participate directly in classified work, their understanding and knowledge, particularly in the theoretical area, have been of great value to the broader direction of defense programs.

Miriam John from Sandia National Laboratories pointed out that despite these ongoing relationships, there is a strong perception that "scientific collaborations between the NNSA (National Nuclear Security Administration) labs and industry, universities and foreign scientists have dramatically declined." The reality is that although the barriers to those collaborations are greater than they have ever been in the past (including new requirements governing visits by foreign nationals, conference attendance, and use of LDRD funds), labs such as Sandia have worked hard to maintain healthy foreign national postdoctoral and visitor programs. Even in the weapons program (e.g., the ASCI), the role of academic collaborative research remains strong. This interaction is critical to keeping the research quality and standards high in the classified arena and maintaining connection for researchers in the classified world with the broader scientific community.

While there are synergies that can be attained through appropriate interactions among researchers in the classified and unclassified arenas, according to Trewhella, capitalizing on these benefits requires the following systems to be put in place:

- Effective processes for compartmentalizing the research and creating and maintaining barriers between what is open and what must be kept secret
- Effective review mechanisms in all partitions
- Strong partnerships with the best universities—focus on key skills
- Strategic targeting of collaborations in open research areas that support national security S&T needs

Access issues were also raised as an important element in allowing workers to gather, share insights, and review research. Most of the labs are employing a "graded approach for site access" with specific visitor policies that allow open access to at least a small portion of the laboratory.

[1]This section draws heavily on remarks made by Jill Trewhella on "Conducting the Best Research in a Classified Environment" at the workshop.

Comparison Study with Other Federal Agency Laboratories

To put the DOE contractor-run national laboratories in the broader perspective of the federal laboratory system, two presentations were invited from federal laboratories not run by DOE, namely those operated by NIST and DOD. The NIST presentation by Michael Casassa featured a user facility run by NIST (NIST Center for Neutron Research), not too dissimilar from the user facilities at DOE laboratories. This center had, however, been successful in attracting investment from NSF and NIH, and whereas NIH funding had been mentioned prominently in several of the DOE laboratory presentations, NSF funding was specifically mentioned by participants as difficult to integrate into DOE laboratory projects.

The National Institute of Standards and Technology also operates several joint centers, including the Center for Advanced Research in Biotechnology and JILA (the acronym originally derived from "Joint Institute for Laboratory Astrophysics"). Whereas many of the DOE centers featured in the workshop program were dedicated primarily toward joint research, the JILA center was clearly dedicated towards advanced education as its first objective, with a "staff" dominated by graduate students. Intellectual property and sensitive but unclassified information were seen as issues in the NIST partnership activities with universities; not mentioned were issues of "color-of-money or pot-of-money" dilemmas, accounting and legal transactional difficulties, prohibitions on foreign student involvement, and the need for mission clarification to the public and Congress—issues that dominated the discussion of many DOE endeavors (see Appendix E). There also seemed to be more commonalities in the types of research performed by NIST researchers vis-à-vis university researchers, particularly within JILA: the examples given by Casassa suggested that much NIST research was also individual PI-driven and much less involved in the "big complicated engineering team science" endeavors characteristic of DOE laboratories. Stable long-term funding and monetary or risk buy-in from both sides of a university-lab partnership were concluding requirements for success that echoed earlier sentiments presented by DOE laboratory representatives Jeffrey Wadsworth and Robert Rosner.

The extensive involvement of DOD with universities at all levels is driven by a need to keep DOD ideas and people current with the latest technological developments. With respect to DOD interactions with universities, Kenneth Harwell's presentation illustrated that, first and foremost, much of this interaction was in the form of grants given to universities for the purpose of conducting research, acquiring instrumentation, and educating advanced degree students. The analogue would be Office of Science grants given to universities by DOE (i.e., a program at the agency level, not the laboratory level). However, whereas the Office of Science does not give student fellowships directly, DOD does (e.g., the Defense Science and Engineering Graduate Fellowship Program). This distinction means that DOD-funded fellows typically have much less extensive person-to-person partnering and research interaction than their DOE counterparts, who are sponsored and mentored directly by laboratory personnel. Cooperative and summer employment programs as described by Harwell, appeared to be much more similar in their implementation between DOD and DOE. Joint faculty appointments between DOD laboratories and universities were not mentioned and presumably do not exist, even though a number of joint centers were mentioned (e.g., the Collaborative Center in Control Science, the Collaborative Center for Polymer Photonics, the Information Institute).

Absent in the DOD presentation were any references to color-of-money or pot-of-money, administrative, or legal issues in collaborations, presumably because the origin of both money and contracts is the same for all potential collaborators. Also absent were any remarks regarding difficulties in hosting foreign graduate students in the laboratory environment or in the participation of non-citizen, U.S.-residing faculty and students at DOD laboratory events and seminars. Indeed, DOD has gone one step beyond interacting with U.S. researchers of foreign origin and has a dedicated program, "Windows on Science," to sponsor visits of leading foreign researchers to DOD laboratories in order to capture the latest technological developments and research concepts from abroad.

Conspicuously present in Harwell's presentation were a number of DOD collaborative programs with universities that also had substantial industry contributions. This is in contrast to the DOE national laboratory/university interactions discussed earlier, which tended to be much more bilateral. For example, some DOD programs (e.g., the GICUR [Government Industry Co-sponsorship of University Research] program presented by Harwell) required 1:1 agency-industry cost sharing for the university programs it supported. As another example, the DOD Federated Laboratory-Collaborative Technology Alliances were heavy with industrial members, and the alliances attempt to institutionalize rotation from both the industry and the university sectors into the defense laboratories. Presumably this is not possible in a DOE national laboratory context because of stricter clearance requirements even for site entry, as discussed earlier.

A unique concept presented by Harwell—apparently without analogue on the DOE side—was the formation of a $17.7 million private not-for-profit 501(c)(3) corporation to further DOD's research interests in aerospace. The Wright Brothers Institute, as it is called, sponsors research project collaborations, research chairs at universities, technology incubators, and research and business planning activities. It is governed by its own board of directors, which includes representatives from government, university, and industry. Funding derives primarily from the Air Force Research Laboratory (through congressional appropriation), local economic development concerns, and the state government.

Throughout the DOE, DOD, and NIST presentations, there was an interesting divergence on the self-image of the federal laboratory researcher. All plenary speakers implicitly or explicitly recognized that much of the nation's leading-edge research occurred in universities. However, several of the DOE presenters stressed that the scientists in national laboratories deliver equally significant scientific breakthroughs and therefore aspire to be recognized as leading-edge researchers at the same level, and in the same context, as university researchers (hence, the "prestige" afforded by university titles). Many of the leading scientists at DOE laboratories have in fact come from leading research universities and retain a culture that is focused on peer-reviewed and path-breaking science. The NIST presentation made no such reference or distinctions, implicitly suggesting that visibility and recognition were not issues for NIST researchers and that, given equal contributions, they enjoyed equal access to the public stage.

The DOD presentation, in yet a third variant, suggested that university researchers would inevitably dominate the intellectual forefront and world scientific stage and that the role of the mission-oriented laboratory researcher was to translate some of these advances into technology. This point of view came out most clearly in slides describing the Air Force Research Laboratory's Information Institute, where the benefits received *from* the university included "early access to innovation," "stay[ing] abreast of technology trends," and "serv[ing] as mentors to staff," while benefits *to* the university included many funding-related items (e.g., "financial support for research," "employment opportunities," "sabbatical leave opportunities," "connection to research opportunities within AFOSR" [Air Force Office of Scientific Research, the primary Air Force funding agency for universities]), as well as the ability to work on interesting, technology-driven problems.

In short, the two non-DOE federal laboratory speakers presented scenarios that differed from DOE in several key areas, thereby identifying issues that are unique to DOE:

1. Significant accounting, contracting, and legal hurdles in university collaborations, which—aside from IP (intellectual property) issues—appear to be unique to DOE. Discussions in breakout sessions suggest that these stem from the GOCO (government-owned, contractor-operated) model that DOE uses to run its laboratories. Such problems are ameliorated somewhat when the university operates the laboratory.

2. Color- or pot-of-money problems in conducting collaboration and education programs with universities appear unique to DOE. Audience comments indicate this problem arises from DOE's use of outside contractors to run its laboratories. For example, there are moneys that derive from the contractors' other operations, money that comes to the contractor from DOE for the purpose of running the laboratory, money that comes to the contractor as "profit" on running the laboratory (performance-based incentive for the contractor), and outside moneys raised by laboratory researchers through successful grant writing to companies, foundations, or even other agencies. Each "pot" comes with its own restrictions. Participants' stories illustrated that even funds that originate from one source, the Basic Energy Sciences Division of the DOE Office of Science (DOE-BES) for example, have different restrictions on them, depending on the origin and destination. Large facilities expenditures often come in as line items in the congressional budget. Single or group PI work typically comes in as field work proposals. Grant instruments, the funding mechanism most familiar to university faculty funded by DOE, is not available to DOE laboratory researchers: DOE regulations prohibit the use of its own grant mechanism to fund work at the national laboratories. However, DOE national laboratory researchers are allowed to respond to grant solicitations from NIH, thanks to a 1998 MOU between DOE and NIH that authorizes DOE laboratory contractors to be the institutional entity submitting the NIH grant application. Thus, because DOE researchers are supported by both non-government and government funding sources, and even sub-classifications of funding within each, they are more susceptible than most researchers to the problem of differing contractual restrictions on the funds they receive.

3. DOE has much stricter controls on foreign nationals, foreign visitors, and hence university collaborations than other agencies' laboratories, even DOD.

The presentations from other agencies' point of view also revealed some comparative truths about DOE laboratories and their researchers:

- DOE researchers view themselves as competitive with, and competitive for, the same levels of intellectual achievement and global prestige as university professors.
- DOE researchers view their research as an unusual blend of cutting-edge basic science and engineering and equipment-intensive experimentation (often at large scale), with a strong professional staff and team-oriented approach not duplicated in any other type of facility.

Appendixes

Appendix A

Committee Member Biographies

Jerome Grossman (C*hair*) is a senior fellow at the John F. Kennedy School of Government at Harvard University and a member of the Institute of Medicine of the National Academies. Dr. Grossman currently chairs the Research Commercialization Working Group of the Government-University-Industry Research Roundtable at the National Academies, which has recently focused its efforts on university-national laboratory relationships. Outside of his work at the Academies, Dr. Grossman is director of the Health Care Delivery Project at Harvard, bringing his expertise in the health care system and information technology and his experience in community services to develop innovations and reforms in the medical care delivery system. He is chairman emeritus of New England Medical Center, Inc., where he served as chairman and CEO from 1979 to 1995, and is an honorary physician at the Massachusetts General Hospital. In 1990, he was named a director of the Federal Reserve Bank of Boston and was appointed chairman from 1994 to 1997. Grossman has been a member of the founding team of several health care companies and has held teaching, research, and medical positions at Tufts University School of Medicine, Massachusetts General Hospital, and Harvard Medical School.

Charlette Geffen is currently a product line manager in the Atmospheric Science and Global Change Division at the Pacific Northwest National Laboratory (PNNL), operated for the Department of Energy by Battelle Memorial Institute. Her primary responsibilities include business development and program management for the atmospheric science and climate policy research programs at PNNL. Prior to taking on this assignment, she served as associate director for strategic planning at PNNL. Dr. Geffen has been with PNNL since 1977, with more than 25 years of experience in strategic technology planning and assessment, environmental regulatory policy and risk assessment for energy, environmental management, and transportation systems. Dr. Geffen is recognized for her strengths in building and managing teams to achieve results and has had significant program and line management responsibilities at PNNL, including leadership of a research group in Washington, D.C., focused on energy and environmental policy. Dr. Geffen holds a B.S. in civil and environmental engineering from Stanford University, an M.B.A. from the University of Washington, and a Ph.D. in technology management and policy from the Massachusetts Institute of Technology. Dr. Geffen is also an adjunct faculty member in the Business School at Washington State University, Tri-Cities, where she teaches graduate courses in technology strategy and management of R&D.

Dan Hartley retired from Sandia National Laboratories as vice president for laboratory development. In that role he was responsible for strategic management of the laboratories including management of an $80 million dollar discretionary research fund, leadership in strategic planning, business development, industry and university partnerships, congressional relations and information technology. His 31 years of experience have included 18 years at Sandia's Livermore, California site where he founded and developed DOE's Combustion Research Facility, a premier international research center. In his role as vice president of laboratory development, which began in 1995, Dr. Hartley personally emphasized the development of industry and university partnerships. Under his leadership, Sandia has been recognized as a leader in partnerships among the DOE national laboratories. He is frequently invited to speak on partnerships and has testified before Congress on their merits and challenges. He served as chairman of the AMTEX (American Textile) Industry-Lab Partnership Board. Dr. Hartley founded the Sandia Science and Technology Park and developed supporting relationships with the Department of Energy, the City of Albuquerque, and the State of New Mexico. Since retiring from Sandia, Dr. Hartley has remained active in university advisory roles, and economic development across New Mexico; he is chairman of the board of Khoral Research Inc., a software company in Albuquerque.

John Peoples is a senior scientist in the Fermilab Experimental Astrophysics Group and director of the Sloan Digital Sky Survey. He joined Fermilab in 1972 and, over the course of 16 years was engaged in the construction and management of experimental facilities and accelerators for high-energy physics. He had held the positions of both deputy director and director and was appointed director emeritus in 1999. A fellow of the American Physical Society (APS) and the American Association for the Advancement of Science, Peoples is currently the Chair of the Space Telescope Science Institute Visiting Committee. He also chairs the Cost and Schedule Review Committee for the Large Hadron Collider (European Center for Particle Physics). Dr. Peoples is currently a member of the Spallation Neutron Source Advisory Board, the University of California Science and Technology Panel, and the APS Committee of International Scientific Affairs. He received the Distinguished Associate Award in 1995 from the Secretary of Energy and the Distinguished Service Award from the Directorate for Mathematical and Physical Sciences of the National Science Foundation in 1999. Peoples received his Ph.D. in physics from Columbia University. He has served on two National Academy committees.

Julia Weertman's areas of research and teaching center on the mechanical behavior of metals and alloys and the underlying phenomena that give rise to the observed behavior. Her research currently is focused on determining the mechanical properties of a variety of nanocrystalline materials, characterizing their structure, and studying deformation mechanisms in this small grain-size regime. She also continues to be interested in the high-temperature behavior of metals. Her research has demonstrated the value of small-angle neutron scattering for detection and quantification of such features as voids and pores and for following nucleation and growth kinetics of second-phase particles. Professor Weertman is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. She is a member of the Committee on Women in Science and Engineering and a past member of the Committee on Human Rights of the National Academies, and has served on several National Research Council (NRC) panels. Currently she is a member of the NRC National Materials Advisory Board. She has also served on advisory panels for DOE and NSF and for several national laboratories.

Robert Zimmer is provost and professor of mathematics at Brown University. Prior to joining Brown, Dr. Zimmer served in a number of administrative capacities at the University of Chicago, culminating in his appointment as vice president for research, and for Argonne National Laboratory where he focused on the interface and interaction between national laboratories and universities. A graduate of Brandeis University, Zimmer earned his graduate degrees at Harvard in mathematics. He began his academic career as assistant professor of mathematics at the U.S. Naval Academy, and later joined the University of Chicago faculty.

He has also held visiting positions and long-term summer appointments at universities in Europe, Australia, and Israel. The author of two books and more than 80 research articles, Zimmer's primary intellectual interests include ergodic theory, Lie groups, discrete subgroups, differential geometry, transformation groups, group representations, foliations and related questions of geometry, group theory, and analysis. He has served on the editorial boards of *Ergodic Theory and Dynamical Systems*, *Transactions of the American Mathematical Society*, *Geometriae Dedicata*, and *Journal of Geometric Analysis* and is series editor of the Chicago Lectures in Mathematics Series.

Appendix B

Workshop Agenda

**NATIONAL LABORATORIES AND UNIVERSITIES:
BUILDING NEW WAYS TO WORK TOGETHER**

**JULY 10-11, 2003
BERKELEY, CALIFORNIA**

**July 10—Lawrence Berkeley National Laboratory
Building 66 Auditorium**

8:00-8:05 Opening Remarks by Jerome Grossman, NRC Committee Chair

8:05-8:10 Charles Shank, Laboratory Director, Lawrence Berkeley National Laboratory

8:10-8:30 John H. Marburger, Director, White House Office of Science and Technology Policy[1]

8:30-8:40 Questions & Answers

[1]Michael Holland substituted for John Marburger on the day of the event.

8:30-9:00 *We All Agree Collaboration Is a Good Thing— So How Can It Be Strengthened? Identification of Structural and Cultural Issues (Distinguished Panel)*

Panelists:
Robert Berdahl, Chancellor, University of California, Berkeley
Jeffrey Wadsworth, Laboratory Director, Oak Ridge National Laboratory

9:00-9:30 Questions & Answers

9:30-10:00 Break

10:00-11:00 *Incentives and Structures: Effective Mechanisms for Collaboration*

Speakers:
Alton Romig, Vice President for Science,Technology and Partnerships, Sandia National Laboratories
Robert Rosner, William E. Wrather Distinguished Service Professor, University of Chicago
Gerry Stokes, Director, Joint Global Change Research Institute, Pacific Northwest National Laboratory

11:00-11:20 Questions & Answers

11:20-12:20 *Conducting the Best Research in a Classified Environment*

Speakers:
Jill Trewhella, Division Leader, Biosciences Division, Los Alamos National Laboratory
Miriam John, Vice President of California Laboratory, Sandia National Laboratories
Dave Mao, Carnegie Institute

12:20-12:40 Questions & Answers

Lunch Presentation: *How Could One Design a Nationwide University-National Laboratory Program on Homeland Security?*

1:15-1:45 Mel Bernstein, Director of University Programs and Fellowships, Department of Homeland Security

2:00-2:20 Break

2:20-3:20 *Collaborations as a Means of Assuring a Sustainable Human Resource Base*

Speakers:
Charlette Geffen, Senior Program Manager, Pacific Northwest National Laboratory
Laura Gilliom, Director of University Relations Programs, Lawrence Livermore National Laboratory
Alex King, Professor and Head, Materials Engineering, Purdue University

3:20-3:40 Questions & Answers

3:40-4:20 *Non-DOE Examples of Collaborative Mechanisms*

Speakers:
Michael Cassasa, Director, Program Office, National Institute of Standards and Technology
Kenneth Harwell, Director, Defense Laboratories Programs Department of Defense

4:20-4:40 Questions & Answers

July 11 – Haas School of Business
Wells Fargo Room, University of California, Berkeley

8:00-9:00 *Best Practices in User Facilities*

Speakers:
William McLean, Director, Combustion Research Facility and Physical Sciences Laboratory, Sandia National Laboratories
Murray Gibson, Associate Laboratory Director, Advanced Photon Source, Argonne National Laboratory
Takeshi Egami, Chair, Spallation Neutron Source and High Flux Isotope Reactor Group, University of Pennsylvania

9:00-9:20 Questions & Answers

9:20-9:40 Break

9:40-11:00 Breakout Sessions

- Policy Options to Provide Incentives and Structures that Promote Collaboration
- Policy Options for Conducting the Best Research in a Classified Environment[2]
- Policy Options for Assuring a Sustainable Human Resource Base
- Policy Options to Assure Best Practices in User Facilities

11:00-11:40 Report of Breakout Sessions (5-minute presentations with 5 minutes of questions and answers)

11:40-12:00 Closing Remarks

12:15 Laboratory Tours

[2]This breakout session was cancelled due to insufficient enrollment on the day of the event.

Appendix C

Workshop Participants

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Jerome Grossman
John F. Kennedy School of Government

Fawwaz Habbal
Harvard University

Dan Hartley
Sandia National Laboratories (retired)

Kenneth Harwell
U.S. Department of Defense

John Hemminger
University of California, Irvine

Brent Hiskey
University of Arizona

Michael Holland
White House Office of Science and Technology Policy

John Holzrichter
Lawrence Livermore National Laboratory

Alan Hurd
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John Peoples
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Leland Younker
Lawrence Livermore National Laboratory

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Appendix D

Glossary of Acronyms

AFOSR—Air Force Office of Scientific Research
ANL—Argonne National Laboratory
APS—Advanced Photon Source
ASCI—Accelerated Strategic Computing Initiative
BNL—Brookhaven National Laboratory
DHS—Department of Homeland Security
DOD—Department of Defense
DOE—Department of Energy
DOE-SC—Department of Energy, Office of Science
GICUR—Government Industry Cosponsorship of University Research
GOCO—government-owned, contractor-operated
IP—intellectual property
JILA—Joint Institute for Laboratory Astrophysics
LANSCE—Lujan Neutron Scattering Center
LANL—Los Alamos National Laboratory
LBL—Lawrence Berkeley Laboratory
LDRD—laboratory-directed research and development
LLNL—Lawrence Livermore National Laboratory
MOU—memorandum of understanding
NIH—National Institutes of Health
NIST—National Institute of Standards and Technology
NNSA—National Nuclear Security Administration (includes LLNL, LANL, and SNL)
NSF—National Science Foundation
OMB—Office of Management and Budget

ORNL—Oak Ridge National Laboratory
OSTP—Office of Science and Technology Policy
PNNL—Pacific Northwest National Laboratory
S&E—science and engineering
S&T—science and technology
SNL—Sandia National Laboratories

Appendix E

Major Benefits and Challenges

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
University as Management Contractor	**Examples:** • University of California operation of LLNL, LANL, LBL • University of Chicago operation of ANL • Southeastern Universities operation of Jefferson Laboratory • University of Tennessee-Battelle operation of ORNL **Benefits:** • Stronger interaction between laboratory and university scientists, by virtue of colocated facilities • Similarities in reward and accounting systems: joint appointments specifically are much easier when accounting systems are compatible **Challenges:** • Political challenges from Congress
Level-by-level Matched Pair Interactions Between Institutions	**Example:** Sandia strategy of teaming each administrative level with its counterpart on the academic side (e.g., its division directors or vice presidents with campus deans/ or administrators, its technical staff with academic faculty). **Benefits:** Ensures duration and consistency at all levels in the institutional relationship **Challenges:** New approach, not yet tested outside SNL
Large User Facility	**Examples:** • Advanced Photon Source (APS) • Stanford Synchrotron Radiation Laboratory • High Flux Isotope Reactor

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Large User Facility	• Lujan Neutron Scattering Center (LANSCE) • Spallation Neutron Source • Environmental Molecular Sciences Laboratory **Benefits:** • Users often actively involved in design via semipermanent build-and-use teams and also in decision making via advisory user groups • User participation (e.g., beamtime allocation) is by an open and well-defined process. Most user facilities have easily navigable web signups; some have hosting facilities for visitors • Use of collaborative scientist teams to partially fund and design user facilities leads to more innovative science results than the government-funds-all approach used in Europe • External science advisory committees also ensure high scientific quality. • Users are 50 percent academic; therefore, there is a direct impact of user facilities on quality of education in the United States • Siting of user facilities at national laboratories enables experiments requiring permanent professional staff (project duration > graduate student lifetime), complex engineering and design expertise, a sustained team approach, and centralized management • User facilities provide a strong political support base because of the many users involved **Challenges:** • Cost for a build-and-use team is hefty—from $2 million to $15 million. • When funding amounts are large, the use teams for each beamline tend to be very large and hence generic. Specialization within a single facility (from beamline to beamline) can be lost • It is not clear that the existing funding model can be used for the next generation of user facilities, which will cost even more. Also, it is easier to obtain funds for construction than for ongoing operations and maintenance—the latter can be a real challenge • Life scientists are becoming the dominant users of some physics-based user facilities, such as the APS, raising an interesting question as to the relative roles of NIH and DOE in the future funding of these facilities • Administrative agreements for university access to user facilities are negotiated on a case-by-case basis at a significant cost in time and manpower. There is a strong need for a standardized MOU between user facilities and universities • Universities that are geographically close to user facilities have the greatest chance of building meaningful collaborations; those far away may feel geographic discrimination. Remote users can be accommodated by virtual capabilities in some facilities, but not most and not well • Though a small portion of the overall user base, industry (e.g., pharmaceutical company)-funded research has IP challenges associated with it

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Large User Facility	• Classified research, particularly the handling of biosensitive materials, is currently not well provided for in user facilities • There is some question as to whether laboratory employees themselves will continue to be able to participate in basic research at user facilities, given funding pressures to move toward applied projects. This loss of basic research activity distances laboratory employees from other users and makes their work more difficult to evaluate by peer review methods
Small User Facility	**Examples:** • Neutron Powder Diffractometer in LANSCE • Nanoscience centers sponsored by Office of Science • Combustion Research Facility **Benefits:** • National Laboratories can build and operate specialized small facilities that universities cannot, particularly those that require (1) significant engineering design and prototyping; (2) full-time, multiyear team operation; (3) centralized planning; and (4) intensive ongoing technical support. Because these required human resources are available only at national laboratories, their small facilities tend to be nationally unique • Funding for $2 million to $20 million facilities is possible in the laboratory context; it is nearly impossible in the university context where equipment proposals are limited to much smaller sums **Challenges:** • The case for the support of these facilities at the national laboratories has not been made clearly to Congress or DOE • Accordingly—and despite their quality—the smaller facilities tend to be characterized by poor national recognition, little advertising within the scientific community, and inconsistent or deficient user support budgets and processes • However, there is no substitute for many of the capabilities offered by these smaller facilities
Joint Institute or Program	**Examples:** • Applied Sciences Program at University of California, Davis (UC Davis-LLNL) • Advanced Materials Laboratory (SNL-University of New Mexico) • Institute for Geophysics and Planetary Physics (LANL and LLNL with four UC campuses) • Global Change Research Institute (PNNL- University of Maryland) • Joint Institute for Nanoscience and Nanotechnology (PNNL-University of Washington) • Joint Institute for Biological Sciences (ORNL-University of Tennessee [UT]) • Joint Institute for Computational Sciences (ORNL-University of Tennessee)

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Joint Institute or Program	**Benefits:** • *On both sides*: science that could not be accomplished otherwise • *For the student*: an additional mentor for the thesis at the national laboratory, plus substantial research time at the laboratory including access to high-caliber equipment • *For the university*: an easier path for funding to and from the national laboratory. Joint institutes can provide an accounting path solution for joint laboratory-university work not otherwise possible with two different accounting or cost differential systems • *For the laboratory*: very high capture rate for future employees—typically 30-50 percent of those who participate in the program **Challenges:** • Long-term commitment is required to see results • Many of the best students are not U.S. citizens • Danger of students being perceived as a "job shop" for the laboratory if controls not instituted • Geographical distance of the institute from one or the other member institutions can be a disincentive to collaboration • Base funding for the institute may or may not exist, and there is no guarantee of big success with initial joint proposals • Intellectual property is a continuing challenge and generally requires case-by-case resolution
Formalized Material or Information-Sharing Arrangements	**Examples**: • Tennessee Mouse Genome Consortium (ORNL-4 Tennessee universities, 1 hospital, 1 medical college) • Oak Ridge Center for Advanced Studies (ORNL-UT and 90 other universities) • ASCI (LLNL-dozens of universities) • Nicholas Center for Structural Genomics and other beamline consortia (ANL) **Benefits:** • Development and growth of regional expertise; increased scientific networking, data access, and material sharing • Possibility of state funding for building construction • Higher success rate for proposals due to existing collaborative networks • Access to and cultivation of minority workforce located at historically black colleges and universities; access to scarce workforce in certain technical areas • Increased access of universities to laboratory facilities **Challenges:** • ASCI appears to be the most prominent example of a success story in this area, but the multilayered structure of that initiative was never replicated elsewhere

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Adjunct Faculty Appointments for Laboratory Personnel at Universities	**Examples:** • PNNL • SNL • LLNL **Benefits:** Increased teaching resources at universities, including the ability to nucleate new fields within the university **Challenges:** Teaching compensation at universities is extremely poor, about $3,500 per semester. Adjunct faculty not necessarily regarded as part of the faculty team
Joint Faculty Appointments	**Examples:** • ORNL-UT (12 positions) • BNL-State University of New York (SUNY), Stony Brook • Argonne National Laboratory–University of Chicago **Benefits:** • Superb flexibility for the individual scientist • Additional laboratory space • Translation of laboratory-based findings to university environment and students • Potential recruitment bridge for labs to obtain high-quality students as future employees • Prestige for laboratory employees carrying university title • Reduction of cultural barriers between laboratory and university when there are joint professors who routinely make the crossover • Sabbaticals can be used to support professors at laboratories for short periods of time, even when joint appointments are not possible **Challenges:** • Very difficult to surmount different accounting or overhead systems with a single salary package when the laboratory is not owned by a university • For contractor-managed laboratories, different accounting systems typically lead to double overhead for both salaries and projects • Joint faculty appointments require physical proximity between institutions and consistent performance metrics across the institutions **Creative Solution:** *A joint institute can be an "accounting path solution" for institutions with differing salary and overhead structures, who would otherwise find such appointments impossible*
Collaborative Projects (by individual co-PIs or joint groups)	**Examples:** Grid Computing Project at ANL and many others **Benefits:** • *For both sides*: an ability to do scientific projects not possible without both sets of expertise. For example, Grid Computing Project won many prizes for breakthrough work

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Collaborative Projects (by individual co-PIs or joint groups)	• *For the laboratories*: access to students participating in the projects as prospective employees. Also, increased retention of the highest-quality scientists, who might go elsewhere without cutting-edge research opportunities and the accompanying peer recognition. Ability of scientists doing classified work to have their more fundamental, unclassified ideas thoroughly vetted and critiqued by the scientific community—resulting in much higher-quality work on the classified side • *For the universities*: partial support and training of involved students; access to unique equipment; and substantial technician, engineering, and programmer support. These permanent professional staff are especially difficult to find at universities • University researchers also gain the ability to be involved in a scientific endeavor that lasts more than the lifetime of a single graduate student. **Challenges:** • Time scale of individual laboratory projects much shorter than university thesis, leading to differing views of end points and mismatched rates of progress • Not all administrators understand, value, or reward collaboration across sectors. Untenured faculty are particularly at risk if they invest too much in collaboration. Specifically, team science is rewarded in national laboratories, while individual PI science is rewarded in universities • Universities may view labs as source of money only or as competitor for funding, in which case the goals are not necessarily shared and the collaboration suffers. Possible perceptions of competition can be ameliorated by collaborating with those most concerned • Security considerations generally require separate computer networks • Lack of education or research as explicit, well-understood (and funded) missions of DOE prevents the labs and their employees from pursuing collaborations or student cultivation to the extent they might be able to otherwise • Significant color-of-money problems: — University and laboratory researchers cannot be co-PIs on the same grant application, meaning one has to be in a subcontractor (inferior position) to the other — Only certain moneys (in scarce supply) can be used to sponsor visits of collaborators to the labs — Some labs have no "color" of money that can be used to sponsor laboratory involvement in a university consortium • Reduction in LDRD money at the laboratories has limited the amount of inquiry-driven (i.e., university-amenable) research that can be conducted, as well as the extent of interaction with university students • Lack of "white space" (unclassified meeting space) within the labs makes it difficult for collaborators to give presentations on their work to laboratory employees

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Collaborative Projects (by individual co-PIs or joint groups)	• Intellectual property and other clauses in research contracts, grants, "work for hire" are the source of much institutional disagreement and exacerbating delays. ("The scientists are ready to go, and the lawyers can't work it out") **Creative Solution:** *Where possible, use NIH as a funding source for collaborations involving national laboratory and university researchers: both researchers can be on the same proposal*
Postdoctoral Fellowship Programs	**Examples:** • Lawrence fellows (LLNL) • Oppenheimer fellows (LANL) • Sandia Doctoral Fellowship Program **Benefits:** • High-stipend postdoctoral fellows are "the cream of the crop," exceptionally well qualified • The programs successfully convert 30-50 percent of their participants to national laboratory employees **Challenges:** • Many of the most highly qualified applicants are not U.S. citizens. Converting them to national laboratory employees requires extensive bureaucracy, including assurance programs for green card applications, sequential or extended temporary positions until citizenship is granted, and cyber access
Student Outreach	**Examples:** • Student Research Apprentice Program at PNNL • Classroom studies and laboratory visits by students to the High Field Magnetic Resonance Facility at PNNL • University Relations Program at LLNL • Student Employee Graduate Research Fellowship Program at LLNL **Benefits** (anticipated): Robust future workforce **Challenges:** • Congressionally mandated cutbacks for education programs in the Office of Science (from $60 million to $6 million) meant that many broad-based efforts were abandoned. Most efforts are now limited to individual laboratories • Travel support to the labs for students and professors is lacking—virtually every pot of money is the "wrong" color for this purpose • Meaningful interactions at the undergraduate level limited primarily to institutions within 2 hours of each other • Graduates in some areas of specialization (radiochemistry, nuclear engineering) are in perilously short supply; may require coordinated outreach, scholarship, and support programs by national laboratories and affected agencies (DOE, DOD, National Aeronautics and Space Administration, Defense Threat Reduction Agency)

Type of Collaboration	Examples, Benefits, Challenges and Solutions (where indicated)
Student Outreach	• Disappearance and/or inconsistent application of agency-supported graduate programs is a partial contributor to current workforce deficit in critical skills • Large fraction of advanced technical workforce is of non-U.S. origin; visa hassles and expectation of poor treatment by authorities have made these best and brightest increasingly inaccessible to the laboratories