2003-2004 Assessment of the Army Research Laboratory

ISBN
978-0-309-29711-0

140 pages
8.5 X 11
2005

Army Research Laboratory Technical Assessment Board; Division on Engineering and Physical Sciences; National Research Council

2003-2004 Assessment of the Army Research Laboratory

Army Research Laboratory Technical Assessment Board
Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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

THE NATIONAL ACADEMIES PRESS **500 Fifth Street, N.W.** **Washington, DC 20001**

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Board responsible for the report were chosen for their special competences and with regard for appropriate balance.

This study was supported by Contract No. DAAD17-03-C-0017 between the National Academy of Sciences and the Army Research Laboratory. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

Copies of this report are available from the Army Research Laboratory Technical Assessment Board, The National Academies, 500 Fifth Street, N.W., 9th Floor, Washington, DC 20001.

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Wm. A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Wm. A. Wulf are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

ARMY RESEARCH LABORATORY TECHNICAL ASSESSMENT BOARD
2003-2004

ROBERT W. BRODERSEN, University of California at Berkeley, *Chair*
GEORGE E. DIETER, University of Maryland (Emeritus)
CLIVE L. DYM, Harvey Mudd College
DAVID R. FERGUSON, Boeing Information and Support Services
DOUGLAS H. HARRIS, Anacapa Sciences
MARY JANE IRWIN, Pennsylvania State University
RICHARD S. MULLER (2003), University of California at Berkeley
JOHN C. SOMMERER (2003), Johns Hopkins University Applied Physics Laboratory
DWIGHT C. STREIT, Northrop Grumman Space Technology
DENNIS W. THOMSON, Pennsylvania State University

National Research Council Staff

JAMES P. McGEE, Director
CY L. BUTNER, Senior Program Officer
RADHIKA S. CHARI, Administrative Coordinator
ALLISON E.I. SHOUP, Senior Program Assistant

Acknowledgment of Reviewers

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 National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

James W. Dally, University of Maryland, College Park,
James L. Flanagan, Rutgers, The State University of New Jersey,
James Glimm, State University of New York, Stony Brook,
Thom Hodgson, North Carolina State University,
Harry Lipsitt, Wright State University,
Richard Pew, BBN Technologies,
Charles V. Shank, E.O. Lawrence Berkeley National Laboratory, and
Christine Sloane, General Motors Corporation.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Alton Slay of Slay Enterprises, Inc. Appointed by the National Research Council, he 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.

Contents

2003-2004 Assessment of the Army Research Laboratory

1

Introduction

THE BIENNIAL ASSESSMENT PROCESS

The charge of the Army Research Laboratory Technical Assessment Board (ARLTAB) is to provide biennial assessments of the scientific and technical quality of the Army Research Laboratory (ARL). These assessments include the development of findings and recommendations related to the quality of ARL's research, development, and analysis programs. While the primary role of the Board is to provide peer assessment, it may also offer advice on related matters when requested to do so by the ARL Director; the advice provided focuses on technical rather than programmatic considerations. The Board is assisted by standing National Research Council (NRC) panels that focus on particular portions of the ARL program. The Board's assessments are commissioned by ARL rather than by one of ARL's parent organizations.

The Army Research Laboratory Technical Assessment Board currently consists of 8 leading scientists and engineers whose experience collectively spans the major topics within the scope of ARL. Six panels, one for each of ARL's in-house directorates,[1] report to the Board. Each Board member sits on a panel, 6 of them as panel chairs. The panels range in size from 9 to 20 members, whose expertise is tailored to the technical fields covered by the directorate(s) that they review. In total, 82 experts participated, without compensation, in the process that led to this report.

The Board and panels are appointed by the National Research Council with an eye to assembling

[1]The six ARL directorates are the Computational and Information Sciences Directorate (CISD), Human Research and Engineering Directorate (HRED), Sensors and Electron Devices Directorate (SEDD), Survivability and Lethality Analysis Directorate (SLAD), Vehicle Technology Directorate (VTD), and Weapons and Materials Research Directorate (WMRD) (see Appendix A, which contains an ARL organizational chart as well as a tabulation of ARL funding by technical unit). The Board does not have a panel specifically devoted to the Army Research Office (ARO), which is another unit of ARL, but all Board panels examine how well ARO and ARL's in-house research and development are coordinated.

balanced slates of experts without conflicts of interest and with balanced perspectives. The 82 experts include current and former executives and research staff from industrial research and development (R&D) laboratories, leading academic researchers, and staff from Department of Energy (DOE) national laboratories and federally funded R&D centers. Fifteen of them are members of the National Academy of Engineering (NAE), a number have been leaders in relevant professional societies, and several are current or past members of organizations such as the Army Science Board, the Air Force Scientific Advisory Board, the Air Force Weapons Laboratory, and the Defense Advanced Research Projects Agency (DARPA).

The Board and its panels are supported by National Research Council staff, who interact with ARL on a continuing basis to ensure that the Board and panels receive the information they need to carry out their assessments. Board and panel members serve for finite terms, generally of 4 years, staggered so that there is regular turnover and a refreshing of viewpoints.

Biographical information on the Board and panel members appears in Appendix B, along with a chart listing the Board membership and the name of each panel, its membership, and the name of the ARL directorate that it reviews.

Preparation and Organization of This Report

The current report is the third biennial report of the Board. Its first biennial report appeared in 2000, and annual reviews by the Board appeared in 1996, 1997, and 1998. As with the earlier reviews, this report contains the Board's judgments about the quality of ARL's work (Chapters 2 through 7 focus on the individual directorates). The rest of this chapter explains the rich set of interactions that support those judgments.

The amount of information that is funneled to the Board, including the consensus evaluations of the recognized experts who make up the Board's panels, provides a solid foundation for a thorough peer review. This review is based on a large amount of information received from ARL and on panel interactions with ARL staff. Most of the information exchange occurs during the annual meetings convened by each panel at the appropriate ARL sites. In both scheduled meetings and less formal interactions, ARL evinces a very healthy level of exchange and acceptance of external comments. The assessment panels engaged in many constructive interactions during their annual site visits in 2003 and 2004. In addition, useful collegial exchanges have taken place between panel members and individual ARL investigators outside of meetings as ARL staff members seek additional clarification about panel comments or questions and take advantage of panel members' contacts and sources of information.

Agendas for the 2003 and 2004 meetings of the panels are presented in Appendix C. Panel meetings last for 2 or 2½ days, during which time the panel members receive a combination of overview briefings by ARL management and technical briefings by ARL staff. Prior to the meetings, some panels receive extensive materials for review, including staff publications.

The overview briefings bring the panels up to date on the Army's long-range planning. This context-building step is needed because the panels are purposely composed mostly of people who—while experts in the technical fields covered by the directorates(s) they review—are not engaged in work focused on Army matters. Technical briefings for the panels focus on the research and development goals, strategies, methodologies, and results of selected projects at the laboratory. Briefings are targeted toward coverage of a representative sample of each directorate's work over the 2-year assessment cycle.

Ample time during both overview and technical briefings is devoted to discussion, both to clarify a panel's understanding and to convey the observations and understandings of individual panel members to ARL's scientists and engineers (S&Es). The panels also devote sufficient time to closed-session deliberations, during which they develop consensus findings and identify important issues or gaps in the panel's understanding. Those issues or gaps are discussed during follow-up sessions with ARL staff so that the panel is confident of the accuracy and completeness of its assessments. Panel members continue to refine their findings, conclusions, and recommendations during written exchanges and teleconferences after the meetings. When necessary, the panels receive presentations that are classified at the Department of Defense (DOD) "Secret" level. This report does not contain classified information.

In addition to the insights gained from the panel meetings, Board members receive exposure to ARL and its staff at Board meetings each winter. Also, some panel members attend the annual planning meetings for ARL's Sensors and Electron Devices Directorate (SEDD) and Weapons and Materials Research Directorate (WMRD), at which those directorates discuss their programs with the directorates' customers. In addition, several Board members attended the 2003 and 2004 symposia that highlight progress among ARL's Collaborative Technology Alliances (CTAs).

As previously noted, each panel normally reviews the work of a single ARL directorate. In 2004, at the request of the ARL Director, the Board undertook two additional reviews, forming two teams that assessed the activities within ARL that cut across several of its directorates in the areas of nanotechnology and robotics. The membership of each of the two review teams was drawn from several panels and was tailored to the areas of expertise required to address the crosscutting nanotechnology and robotics activities. These reviews are intended to help ARL identify interactions, interdependencies, and opportunities for synergy across its directorates as well as the state of the art of its nanotechnology and robotics R&D. Chapters 8 and 9 in this report summarize the results of those crosscutting reviews.

Assessment Criteria

The Board and panels applied assessment criteria organized by six categories (Appendix D presents the complete set of assessment criteria):

1. *Effectiveness of interaction with the scientific and technical community:* criteria that indicate cognizance of and contribution to the scientific and technical community whose activities are relevant to the work performed at ARL.
2. *Impact on customers:* criteria that indicate cognizance of and contribution in response to the needs of the Army customers who fund and benefit from ARL R&D.
3. *Formulation of projects' goals and plans:* criteria that indicate the extent to which projects address ARL strategic goals and are planned effectively to achieve stated objectives.
4. *R&D methodology:* criteria that indicate the appropriateness of the hypotheses that drive the research, of the tools and methods applied to the collection and analysis of data, and of the judgments about future directions of the research.
5. *Capabilities and resources:* criteria that indicate whether current and projected equipment, facilities, and human resources are appropriate to achieve success of the projects.
6. *Responsiveness to the Board's recommendations:* The Board does not consider itself to be an oversight committee. The Board has consistently found ARL to be extremely responsive to its advice, and so the criterion of responsiveness encourages discussion of the variables and contextual factors that affect ARL's implementation of responses to recommendations, rather than an accounting of responses to the Board's recommendations.

Completion of the Report

In July 2004, the Board met for 2 days to share members' summaries of their panels' observations and concerns. This report represents the Board's consensus findings and recommendations. The Board's aim with this report is to provide guidance to the ARL Director that will help ARL sustain its process of continuous improvement. To that end, the Board examined its extensive and detailed notes from the many Board, panel, and individual interactions with ARL over the 2003-2004 period. From those notes it distilled a short list of the main trends, opportunities, and challenges that merit attention at the level of the ARL Director. The Board used that list as the basis for this report. Specific ARL projects are used to illustrate these points in the following chapters when it is helpful to do so, but the Board did not aim to present the Director with a detailed account of 2 years' worth of interactions with bench scientists. The draft of this report was subsequently honed and reviewed according to NRC procedures before being released.

ARMY RESEARCH LABORATORY SUPPORT FOR WAR-RELATED OPERATIONS

This is an extraordinary time for the Army Research Laboratory and indeed for the country as a whole. Examining ARL's support to current war efforts was not a direct charge to the Board, but it became apparent that in addition to performing its typical R&D functions for the Army, ARL has responded quickly and effectively, applying its multiple talents to addressing serious problems as they have arisen in war-related operations in Iraq and Afghanistan. ARL is to be commended for its dedicated and skilled efforts, which have saved warfighter lives and equipment and enhanced the capabilities of U.S. forces. Contributions have come from across ARL.

ARL's current contributions in this arena reflect its unique role as the link within the Army between scientific and technical expertise and specific Army applications—a role that requires maintaining its preparation to contribute when problems arise in the field. This link and consistent contributions have existed across previous war efforts; only the contributions to the current war efforts are discussed here. The Computational and Information Sciences Directorate (CISD) currently has one soldier in Iraq, and an Army Reservist working for the directorate has returned from a 1-year deployment. CISD has supported and continues to support ongoing operations in Afghanistan, Iraq, and other places through its support of multiple programs, including the following:

- *PacBots*. These small robots have been deployed to Afghanistan to help clear bunkers, ammunition caches, caves, buildings, and walled compounds;
- *Phraselator*. This device provides one-way language translation support in a ruggedized personal digital assistant (PDA);
- *Forward Area Language Converter (FALCon).* CISD conducts multilingual research to provide tools for translating documents found in the theater;
- *Document Exploitation Suite (DOCEX).* This high-speed, adaptable capability aids in identifying, prioritizing, translating, and managing foreign language materials by automating the handling of foreign documents and media;
- *Integrated Meteorological System (IMETS).* The Army's weather information management system and the weather component for Intelligence Preparation of the Battlefield, IMETS is intended to provide commanders with automated weather observations, forecasts, battlefield visualization, and weather effects decision aids; and
- *Acoustic Battlefield Aid.* This tactical decision aid uses acoustic sound propagation to identify

areas in which U.S. military assets can be seen and/or heard or not seen and/or not heard. ARL conducts research for the development and evaluation of acoustic propagation models for use in the long-range detection of infrasonic signals (<10 Hz). (Infrasound monitoring examines signatures from human-made and naturally occurring infrasonic sources and the environmental impact on the signals.) ARL also installed an infrasound array and supported data collection and analyses in Korea.

Two employees of the Human Research and Engineering Directorate (HRED) supported Operation Enduring Freedom as part of the Army Materiel Command Logistical Support Element in Southwest Asia during fiscal year (FY) 2003-2004. Also, in collaboration with Carnegie Mellon University and with support from the program manager for Close Combat Systems, HRED significantly improved the probability of detecting low-metal land mines—to greater than 98 percent—using the Army's newly employed AN/PSS-14 Handheld Standoff Mine Detector System by applying MANPRINT (Manpower and Personnel Integration) throughout the acquisition cycle.

The Sensors and Electron Devices Directorate (SEDD) has provided active support to war-related operations. For SEDD, three individuals are or were in the field, and 38 individuals are supporting theater (e.g., Iraq, Afghanistan) projects. SEDD efforts include the following:

- *Acoustic localization for sniper and mortar detection.* The effort in this area led to the fielding of systems in 45 days;
- *Acoustic database.* Data are provided for use with acoustic microsensors;
- *Booby trap detection.* Work in this area led to improved improvised explosive device (IED) detection;
- *HMMWV (High-Mobility Multipurpose Wheeled Vehicle, or "Humvee") gun mount;*
- *Infrasonic arrays* (described above: see item on "Acoustic Battlefield Aid" under CISD efforts); and
- *Initial work on disposable sensing concepts.* This work is focused on sensors for use while clearing buildings during military operations in urban terrain.

During FY 2003-2004, the Survivability and Lethality Analysis Directorate (SLAD) had four individuals in the field and nine supporting theater projects. SLAD anticipated three individuals in theater starting in September 2004. SLAD efforts include the following:

- *Improvised explosive device countermeasure equipment.* This IED countermeasure equipment is expected to be in theater by September 2004, with approximately 500 of the countermeasure devices in theater by the end of November 2004; the U.S. Air Force and other government agencies have also ordered countermeasure devices;
- *Information Assurance Network Assessment.* This assessment will cover the three network architectures currently deployed in theater; and
- *Survivability link between SLAD and deployed units.* This link is being established on the Secret Internet Protocol Router Network (SIPRnet).

The Vehicle Technology Directorate (VTD) has not been directly connected to any current projects in either the Iraq or Afghanistan theaters, but it does consult for Fort Eustis, Virginia, which provides the first line of fleet support in aviation. Moreover, its Active Stall Control Engine Demonstration Program clearly is aimed at a serious problem endemic to those theaters.

The Weapons and Materials Research Directorate's (WMRD's) Terminal Effects Division has had 3 personnel in theater, and approximately 45 WMRD scientists and technicians have been involved in supporting war-related activities. The types of support that they provide and have provided include the following:

- *Design of the rear protection shield for Abrams tanks;*
- *Armor survivability kit for HMMWVs.* ARL built the first 40 of these kits, then transitioned the work to the Tactical Command, which has built more than 10,000 based on ARL's design;
- *Battle damage assessment.* This capability provides technical information on kills to combat vehicles; and
- *Field expedient armor solutions.* This capability provides technical information on ways to improve the survivability of tactical and ground combat vehicles.

CROSSCUTTING ISSUES

In addition to performing special examinations of crosscutting activities in nanotechnology and robotics, described in the last two chapters of this report, the Board also identified three crosscutting issues that are discussed in more detail in Chapters 2 through 7, which summarize the assessments of the directorates. As described below, these issues are modeling and simulation, information assurance and security, and interdirectorate activities.

Modeling and Simulation

The appropriate use of modeling and simulation could be a unifying capability that would have broad implications across many of the ARL directorates. Currently, however, there continue to be key issues relating to modeling and experiments that researchers and investigators have not properly considered. They include the following:

- *Verification* (i.e., that a computer program does what it was intended to do);
- *Validation* (i.e., that the computer program produces results that are valid in and relevant to the domain in which it was intended to operate);
- *Use of a variety of standard operating practices for doing calculations and presenting results* (e.g., the use of appropriate dimensionless variables); and
- *The consequences of the widespread replacement of experiments by computational modeling*.

Addressing these aspects of modeling and simulation could be enhanced by an effort to instruct and support the scientists in the application and science of modeling and simulation techniques. The goal would be to build on top of commercial software whenever possible, but to extend and enhance the modeling and simulation capability to address the particular needs of the various directorates. This support for a modeling and simulation capability, coupled with the enormous computational capability of ARL, could be a unique capability that would enhance the research being performed in a wide number of activities.

ARL is not self-sufficient when it comes to providing its scientists with simulation and modeling capabilities. Rather, it relies on codes developed by other entities. Examples include CTH (Sandia National Laboratories) for explosion dynamics and large-deformation solid mechanics; MM5 (National Center for Atmospheric Research/Pennsylvania State University) for mesoscale atmospheric modeling;

and a variety of National Aeronautics and Space Administration aerodynamics codes. While this is a cost-effective way of providing capability for ARL in many respects, it requires a commitment to acquiring a deep understanding of such codes in-house. This same understanding allows ARL staff to engage the developers seriously in adding capability, or possibly to add the capability themselves. Failing to add needed capability in one way or another can lead to ad hoc efforts to work around gaps in the extramural code, rather than adding permanent new capability to that code. Examples of such projects include the now-casting atmospheric modeling effort within CISD and the munitions modeling code within WMRD. While these are both competently executed efforts, each was based on 20-year-old algorithm technology. Furthermore, since they are based on old technology and are not being incorporated into the mainline production codes, they are unlikely to persist as useful artifacts.

Information Assurance and Security

Information assurance and security are matters of concern across ARL directorates. Both CISD and SLAD, for example, have important roles in this area. The Board believes that CISD should be taking a larger role within ARL and that insufficient resources (staffing), rather than a lack of interest, are preventing the directorate from fulfilling this role.

Information security issues arise internally at ARL as well, in that a significant amount of code being used comes from outside ARL from a variety of sources but there is no clear approach to verifying that it is free from potentially damaging capabilities. A comprehensive strategy should be pursued to assure that the ARL information technology infrastructure cannot be compromised.

Interdirectorate Activities

One of the strengths of ARL is the breadth of activities underway. This makes it possible, if the appropriate leadership and incentives are put in place, to create cross-directorate programs that would exploit the somewhat unique capabilities of ARL. The crosscutting nanotechnology efforts reviewed for this report show potential for going in this direction. While the work reviewed here was a series of relatively independent efforts, it became clear during the review that many opportunities exist for collaborating and developing common infrastructure. Other opportunities for such collaboration are discussed in the individual directorate reports. The process for undertaking this type of collaborative activities is essentially undefined, however, and without sufficient structural facilitations to encourage it. Crosscutting activities such as those discussed here should be strongly encouraged. Doing so will require significant changes in ARL's approach to program management. The Board commends the ARL Director for initiating the crosscutting reviews in the areas of nanotechnology and robotics—these constitute important steps toward identifying programmatic needs and opportunities in these areas and toward learning lessons that can be applied to other crosscutting activities.

2

Computational and Information Sciences Directorate

INTRODUCTION

The Computational and Information Sciences Directorate (CISD) was reviewed by the Panel on Digitization and Communications Science. CISD consists of three research divisions: Computer and Communication Sciences, Battlefield Environment, and High Performance Computing. It also includes one infrastructure division, Information Technology, which serves all of ARL through its computing hardware, software, and staff.

CISD performs research for the following purposes: to help design a robust, highly mobile battlefield communications network while ensuring that the information provided to commanders is current, authentic, accurate, and protected; to develop high-fidelity "micro" weather forecasts in near time (i.e., to predict weather in 10 minutes or less for the next 0 to 2 hours) in order to support combat intelligence operations and troop engagement decisions; to enhance the decision-making prowess of commanders in the battlefield; and to develop robust, physics-based, high-performance computing models and software for concept evaluation, design, and analysis (usually in support of computational science efforts in other ARL directorates).

Tables A.1 and A.2 in Appendix A respectively characterize the funding profile and the staffing profile for CISD.

ACCOMPLISHMENTS AND OPPORTUNITIES

The Digitization and Communications Science Panel that reviews CISD yearly has continued to see improvements in the quality of the research being performed by CISD researchers and in the demonstration of the relevance of their work to Army needs. CISD has, like much of ARL, undergone significant leadership change in the recent past, with its director retiring in mid-2003 and the subsequent appointment of an acting director. In addition, several of the division director and branch chief positions in CISD are filled by acting personnel, while the permanent staff have been given the opportunity to serve ARL in acting positions at higher levels. Adding to the staffing milieu is that at least one of the current division directors is due to retire soon.

CISD is participating in two large, 5-year projects, both of which started in FY 2003: Horizontal Fusion (HF) and Command and Control in Complex and Urban Terrains (C2CUT). The Department of Defense's (DOD's) Horizontal Fusion project is developing network-centric access for the warfighter—access that is "pull-based" rather than dissemination-based. ARL's participation (totaling about $17.5 million in FY 2004) in Horizontal Fusion is currently in basic language translation services (BLTS), in the development of secure mobile networks, and in the Warrior's Edge program.

CISD's advancements in BLTS have made available information that is gleaned through the translation of both printed documents and speech from sources captured in the field. For example, BLTS allows soldiers to scan in documents written in a foreign language and to receive an English translation seconds later. The mobile wireless networks being developed as part of Horizontal Fusion will provide the warfighter with secure, robust voice and data communication capabilities to enable collaboration even in highly dynamic and unpredictable environments. The Warrior's Edge program will develop a dynamic, ad hoc, networked sensing system (of soldiers and robotic sensors) to allow the monitoring of the battlefield environment.

Horizontal Fusion holds an annual proof-of-concept demonstration called Quantum Leap, the second of which was scheduled for August 2004. The goal of C2CUT is to provide commanders with the ability to see and understand the effects of urban terrain on the battlefield environment. Both of these projects have provided CISD researchers with unique opportunities (and the funding needed to perform the necessary research and development) as well as unique challenges.

Additionally, CISD researchers continue to pursue basic research in mobile (robotic) network sensing, communication, data fusion, basic language translation systems, optical communications systems, environmental modeling and prediction, and in computational modeling and prediction.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

Through both the HF and C2CUT projects, CISD has had the opportunity to contribute in significant ways to the troops in the field. For example, software developed for BLTS has been employed on handheld personal digital assistants (PDAs) in both Iraq and Afghanistan to scan captured documents for keywords that would indicate whether the documents should be set aside for further scrutiny. Warrior's Edge also contains several technologies that have aided soldiers in the field. The PacBot robot was first used in combat in July 2002 to remotely examine caves and a building complex in Nasarat, Afghanistan. In Iraq, the PacBot was used to remotely examine equipment left on an airfield before engineers from the 101st Airborne cleared the runway for humanitarian relief operations. The M Gator MULE (Multifunction Utility/Logistics Equipment) vehicle contains a fusion of networked computers that can sense data from soldiers and unmanned aerial vehicles to aid in sniper detection. It was due to be shipped to Iraq sometime in 2004. An acoustic mortar-fire detection system developed jointly with researchers in the Sensors and Electron Devices Directorate (SEDD) was recently deployed and used successfully in the field in Iraq to determine the location of enemy mortars.

The Integrated Meteorological System (IMETS) is the meteorological component of Intelligence and Electronic Warfare (IEW) software developed by ARL researchers in the CISD's Battlefield Environment Division (BED). IMETS provides commanders with an automated weather system to receive, process, and disseminate weather observations, forecasts, and weather-effects decision aids. A vehicle-mounted configuration of IMETS was first used in Operation Iraqi Freedom and is now fully operational and routinely used in the field. In addition to providing quick delivery of high-quality weather forecasts to warfighters in Afghanistan and Iraq, BED has quickly deployed research acoustical signal observation and processing systems for special target localization and identification. CISD's Battlefield Environment Division has also continued its contribution of special meteorological systems for use in terrorism-related studies of urban-scale meteorological phenomena in national field programs such as those recently conducted in Salt Lake City, Utah, and Oklahoma City.

Contributions to the Broader Community

The combat deployment of forces in Iraq and Afghanistan has certainly impacted the work of the CISD staff. There is clear and obvious pressure to transition new technology to the field as quickly as possible. There is also noticeable and deserved pride in the successes of the systems that have been or are soon to be deployed, and a new level of energy can be sensed in the directorate. However, ARL must also ensure that the research necessary to guarantee the technological advantages of future U.S. forces is also being pursued. Over the long term, it is this basic research that creates the opportunity for leapfrogging technology. ARL and CISD leadership must continually be alert to the need to maintain a balance between the processes of technology development and field transitioning and this longer-term research.

Several basic research efforts in CISD deserve mention. First, there is continuous and impressive research in intelligent optics. Free-space lasers can provide high-bandwidth, covert, rapidly deployable, lightweight (i.e., handheld) ground-to-ground and ground-to-air communication systems. CISD has an impressive research program in free-space lasers (e.g., numerous refereed publications and two recent patents) and in 2002 invested in a free-space optical testbed that contributes significant capability to the intelligent optics efforts.

Historically, the Army's view of the environment has been that it consists of manifold obstacles (e.g., inclement weather, fog, and mud) to be battled and conquered. Today it is recognized that the environment is not just a potpourri of problems; properly understood, it can provide a fighting force with both tactical and strategic superiority. It is to that purpose that the Battlefield Environment Division is directing much of its research program at present. Since the onset of conflict and war in Afghanistan and Iraq, BED has, much to its credit, responded immediately to a number of operational needs by deploying several research systems, notably those necessary to provide cutting-edge weather forecasts and special analysis of acoustical signals.

The Army's needs for detailed and current information about and in the terrestrial and atmospheric boundary layers were once nearly unique. Today it is recognized that there is significant overlap between the Army's long-standing primary interests and the currently expanding demands for environmental data relevant to homeland security. To no small extent this overlap exists because urban areas are the theater of both foreign wars and domestic terrorism. It is factors such as the dimensional scale of a battlefield, the character of the underlying terrain and urban structures, and the time required for the wind to blow a natural or artificial cloud across a battlefield or city that define the atmospheric phenomena which must be observed, understood, modeled, and forecast. Hence, BED's research program must address critical and challenging problems in direct and remote atmospheric sensing, model domain size, and the spatial and temporal resolution required in diverse phenomenological, computational models. Implicit are significant challenges for analysis of the relevant inherently turbulent and chaotic phenomena of interest. These phenomena are not yet within reach of currently available observational systems, nor can the needed computational models be operated, at least on timescales necessary for Army purposes, on the most advanced computer systems available today.

The scope of environmental problems needing study far exceeds the reach and resident expertise of BED and ARL. However, BED is effectively addressing several specific problem areas that are of current critical interest. Nationally leading research is being conducted by the division in atmospheric optical sensing and communications systems as well as in analyses of atmospherically propagated acoustical signals that are essential to high-resolution detection, identification, and localization of noise sources. The noises of greatest interest range from those created by stationary sources, such as individual sniper gunshots or larger ballistic and rocket weapons fire, to noises from complex moving systems such as diverse warfighting and transport vehicles.

Developing and testing the very high resolution atmospheric dynamical analysis and forecast models that are of interest to the Army, and now to homeland security as well, constitute an area of extraordinarily wide-ranging national and international need and attention. In the United States alone, agencies including the National Oceanic and Atmospheric Administration and the National Weather Service, the Department of Energy, the National Aeronautics and Space Administration, the Environmental Protection Agency, and the other armed forces in addition to the Army are all involved in significant model development work. In this research and development arena, BED cannot and should not attempt to compete. Neither its research resources nor personnel are of critical mass for such efforts. However, BED is so involved in research on the atmosphere's boundary layer environment that it can and should serve as a national center of excellence in model validation activity.

If BED is to rise to this challenge and thereby exploit the technological and leadership opportunities now available, some careful strategic planning and effort will be required to refocus and restructure some of the directorate's staff and programs. The Board strongly recommends that action to this end be initiated. In the same regard, the Board recommends that special efforts be made to encourage enhanced interdirectorate collaboration among people working on related environmental problems in CISD/BED, SEDD, and the Survivability and Lethality Analysis Directorate (SLAD). Finally, it should be noted that progress in model validation research also will be required when BED is expected to quantify the credibility, performance, and reliability of the observational systems and forecast models that are to be part of the output of large, crosscutting projects such as Warrior's Edge and C2CUT.

RELEVANCE OF CROSSCUTTING ISSUES TO THIS DIRECTORATE

CISD's computational science and engineering activities include scalable algorithms and tools, scientific visualization and immersive technologies, data mining, metacomputing, numerical analysis, and high-performance networking. These activities are clearly important to the Army's mission. A compelling case can be made that computational science can play an important role in the design and development of future combat systems. However, CISD, and indeed all of ARL, have insufficient staff invested in these activities to make significant advancements in all of the computational science and engineering areas.

CISD's high-performance computing capabilities are available for use by other directorates, and a number of projects within those directorates (e.g., in SEDD, SLAD, and the Weapons and Materials Research Directorate) make extensive use of computation and modeling. However, the little information that the Panel and the Board received on this subject did not convince them that ARL directorates are making effective use of the CISD high-performance computing machinery or that CISD is providing other directorates with support in this area in the form of personnel and expertise (i.e., a computational science capability). Nor were the Panel and the Board convinced that high-performance computing projects in CISD are developed in a manner that is driven by a plan for building up a persisting base of in-house expertise rather than a series of responses to immediate customer needs.

Information assurance and security are areas of concern across ARL directorates. Both CISD and SLAD, for example, have important roles to fulfill in this area. The Board believes that CISD should be taking a larger role in information assurance and security within ARL and that resources (staffing), rather than interest, are preventing it from doing so.

3

Human Research and Engineering Directorate

INTRODUCTION

The Human Research and Engineering Directorate (HRED) was reviewed by the Panel on Soldier Systems. HRED conducts basic and applied research and analysis to enhance soldier performance. A broad-based program of scientific research and technology development is directed toward optimizing soldier performance and soldier-machine interactions so as to maximize battlefield effectiveness. Analyses are conducted to ensure that soldier performance requirements are adequately considered in technology development and system design. HRED is organized in two divisions: Soldier Performance and Human Factors Integration.

Tables A.1 and A.2 in Appendix A respectively characterize the funding profile and the staffing profile for HRED.

CHANGES SINCE THE PREVIOUS REVIEW

HRED is in the process of adjusting its programs to meet the changing requirements for Army transformation—that is, moving from a threat-based approach to a capabilities-based approach that is more compatible with the anticipated security environment. This new military environment, as characterized by the HRED Director, has greater complexity, requires increased strategic responsiveness, reflects changes in the spectrum of conflict, pursues revolutionary technologies, and addresses the emergence of the maneuver unit of action that emphasizes adaptive performance by leaders and teams. Significant changes at the directorate since the previous review include the following:

- The filling of core leadership positions;
- Increases in funding;

- A new, director's initiative in cognitive architecture;
- A new research program on the effects of encapsulation (e.g., working in protective suits) on performance;
- New acquisition-related efforts addressing manpower, personnel, and training (MPT) issues faced by the Future Combat System (FCS);
- The development of databases that are valid for modeling tasks and human performance;
- Upgrades for facilities involved in tactical environment simulation and shooter performance; and
- Increased levels of participation in ARL science and technology objectives.

The directorate has continued to expand its efforts in identifying and satisfying the education and training needs of its staff, including the mentoring and advising of staff members as to the specific requirements for and benefits of advanced training. One example of these expanded efforts is HRED participation in the development and implementation of the human systems integration degree program at the Naval Postgraduate School—five members of the HRED staff are currently participating in that program. Also, HRED has provided instruction during 2003 and 2004 as well as over several previous years through numerous invited lectures and seminars on technical subjects related to HRED projects.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

The Panel and the Board noted an increased level of collaboration among HRED staff across projects, noting in particular the synergy evident between projects involving empirical research and those involving modeling. Significant advances have been made in designing and conducting empirical studies with a view to the data that they might provide to associated modeling efforts. This process and level of collaboration are likely to be even further improved by addressing criteria for moving data and their associated parameters into models.

The development of soldier-centered design tools continues to be one of the most important and potentially valuable programs at HRED. The following quotation from the *2001-2002 Assessment of the Army Research Laboratory* provides a benchmark for the current assessment of this program: "Within HRED, the utilization of models is continuing to increase and become more effective. As a consequence, there is greater need to validate, determine the sensitivity, and define the limits of the models being developed and used."[1] The HRED researchers appear to be fully cognizant of these past assessments and recommendations as they move forward with their modeling program. They have demonstrated an impressive understanding of how the program is related to other programs, of the extent of collaboration required with these other ongoing programs, and of the potential barriers and limitations to the ultimate use of human systems integration modeling.

Two very promising strategies and approaches presented by the research team during this assessment were the linking of the Improved Performance Research Integration Tool (IMPRINT) to the unified modeling language (UML) and the development of new databases for equipment, biomechanics, clothing, and related materials. Such databases are needed to provide a more robust modeling of the

[1] National Research Council. 2003. *2001-2002 Assessment of the Army Research Laboratory.* Washington, D.C.: The National Academies Press, p. 33.

physical environment and of related human interactions now being simulated within the digital human modeling community.

Opportunities and Challenges

The increased collaboration and synergy within HRED can provide a basis for extending collaboration to other ARL directorates. HRED participation in the Board's assessments of crosscutting activities is likely to help identify opportunities at these boundaries of knowledge.

HRED has also established a sound basis—with its present connections to related program activities in the Multidisciplinary University Research Initiative (MURI), the Collaborative Technology Alliance (CTA), and the cognitive modeling community—for expanding its interaction with the external research community and for extending its awareness of the work of other investigators related to HRED projects and programs.

The Manpower and Personnel Integration (MANPRINT) program has high-impact potential for the Army. However, it continues to be limited by not being fully embraced in the procurement process and by additional needs for the development and validation of modeling tools. Impacting the procurement process is mainly a matter of taking advantage of opportunities as they occur (and HRED has done an excellent job of exploiting these opportunities). Model development, by contrast, can be an ongoing, systematic process. Because predictive human models are becoming the source of much of the engineering design guidance provided by the Army, they must be correct. If they are not, a great deal of harm and performance loss will be incurred in Army systems. Support of MANPRINT, then, is another reason why the HRED modeling efforts are so important.

During 2003, HRED had 152 work orders from Army customers in support of Army systems and programs. These work orders had a total value of almost $6.9 million. The Board recognizes that it can be difficult to negotiate with customers to preserve the scientific integrity of research efforts while also meeting pressing customer needs. The Board acknowledges that such negotiations are complicated by time pressures, coordination requirements, scheduling uncertainties, problems in obtaining resources, and the frequent necessity for meeting multiple objectives. Nonetheless, the Board encourages HRED to continue to negotiate with and educate customers in order to preserve the scientific integrity of research efforts.

Additional intensive surveillance and analysis of fatality, injury, and performance databases should be undertaken for purposes of identifying future HRED research opportunities. For example, a recent analysis completed elsewhere found that vehicle-related events (involving both combatant and noncombatant) accounted for a disproportionate number of Army deaths. This information suggests an avenue for bringing about significant reductions in Army fatalities. Another example is the excessive number of musculoskeletal problems that are resulting from manual handling of components, such as those required for fixed-bridge construction. Access to and continuing, systematic review of data from medical and safety databases could help identify important areas for the expansion of HRED research and engineering efforts on problems that will lead to reducing injury and associated costs.

The Board believes that HRED should explore opportunities for employing the Battle Lab at Fort Sill, Oklahoma, in its research efforts. The Board recognizes that the Battle Lab is primarily a training resource and that numerous problems must be overcome in adapting such a resource to research purposes. Nonetheless, it does appear that opportunities exist for leveraging existing automated data collection (such as training data that are currently being collected for playback mode during training exercises) for various types of studies. These would include studies of teamwork, situation awareness, the Objective Force Warrior concept, and the nature and contributions of expertise—that is, the defining of expert teams, of the actions of expert teams, and the way that a novice team develops into an expert team.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

In its 2003 and 2004 on-site reviews of HRED programs, the Panel was impressed with the relevance and scientific merit of the HRED research projects that were presented. It was also impressed by the efforts put forth by HRED to influence systems acquisition and design and by the enthusiasm and professionalism of the HRED scientific and technical staff.

The new HRED initiatives to provide cognitive foundations of performance in military environments—particularly the current efforts on the improvement of shooting performance—reflect responsiveness to the Army's transition needs. The multiple-measures approach to investigating shooting and cortical activity—including the collection and analysis of neurophysiological (electroencephalogram) data, along with objective and subjective measures and the modeling of shooting performance—represents a promising approach to the investigation of cognitive performance in high-stress, multitasking environments. The relevance of cognitive neuroscience to Army requirements and soldier performance research was well established by the researchers. The collaborative links with the external research community (such as MURI, CTA, and the University of Maryland) were impressive.

Research on shooting and cognitive load highlights the challenges of validating simulator data and applying them to cognitive models. The strategy employed in this research, emphasizing a cycle of model exploration, data collection and enhancement, and model modification, is impressive and likely to be very productive in meeting these challenges. The Board recommends the consideration of an expanded model-test-model-test approach that includes the field-test validation of revised models at significant stages in the program.

Research initiated on encapsulation is an ambitious, groundbreaking effort to identify the effects of encapsulation on the mission performance of the dismounted warrior. This research employs a number of measures of cognitive performance and three configurations of soldier equipment. It is also focused on identifying methodologies that might be useful for further research. Moreover, it is a positive example of conducting research with a view toward providing data and results for use in MANPRINT tools such as IMPRINT.

The new acquisition-related efforts addressing manpower, personnel, and training have significant potential payoff for the Army and expand the role of HRED to include a new level of analysis. The Panel and the Board look forward to future developments in this area and encourage the communication of analytical results to program managers and higher-level decision makers.

Maintenance is a particularly good area for MPT analysis, representing the need for systematic analyses of future skill requirements needed in order to maintain complex systems. The analyses of maintenance automation completed to date clearly identified the extent and nature of problems faced by the Future Combat System. The Panel and the Board support the modeling of maintenance tasks as a basis for future analyses and look forward to learning how this will be accomplished.

Contributions to the Broader Community

As mentioned above, HRED has continued to expand its interaction with the external research community and to extend its awareness of the work of other investigators related to HRED projects and programs. For example, the *2001-2002 Assessment of the Army Research Laboratory* recommended the pursuit of connections to related program activities in the MURI, CTA, and cognitive modeling communities. The present assessment found that, subsequent to the earlier review, interactions with these communities were pursued with positive results.

HRED has extended its participation with the scientific community over the past several years through an extensive program of lectures and seminars given by experts outside of HRED. These programs address a variety of technical subjects related to HRED projects. HRED has expanded its interactions with external users of IMPRINT. It has done so in part by providing training for current and potential users of the program. It appears that HRED is becoming a center of excellence for the development and application of human-centered modeling.

RELEVANCE OF CROSSCUTTING ISSUES TO THIS DIRECTORATE

Crosscutting issues on modeling should be relevant to this directorate. As discussed earlier, the development of soldier-centered design tools continues to be one of the most important and potentially valuable programs at HRED. Moreover, the HRED researchers appear to be cognizant of the need for verification and validation, the need to relate their programs to those of others, the extent of collaboration required to meet their objectives, and the potential barriers and limitations to the ultimate use of human systems integration modeling.

4

Sensors and Electron Devices Directorate

INTRODUCTION

The Sensors and Electron Devices Directorate (SEDD) was reviewed by the Panel on Sensors and Electron Devices. SEDD has four divisions that are reviewed by the Panel: Electro-Optics and Photonics, Radio Frequency and Electronics, Signal and Image Processing, and Directed Energy and Power Generation. SEDD also has responsibility for the Advanced Sensors Collaborative Technology Alliance (CTA) and the Power and Energy CTA, and it contributes to the Robotics CTA managed by ARL's Weapons and Materials Research Directorate (WMRD). Each CTA began in 2001 and has a 5-year term, with an option for 3 more years.

Tables A.1 and A.2 in Appendix A respectively characterize the funding profile and the staffing profile for SEDD.

CHANGES SINCE THE PREVIOUS REVIEW

SEDD continues to do an excellent job of maintaining and building its capabilities. During the period from FY 2000 through FY 2003, 92 new staff members were hired, as opposed to the loss of 79, and the percentage of staff with Ph.D.s has steadily increased. The SEDD staff remains enthusiastic about their research, technically competent, and highly qualified.

In past years, the Future Combat Systems (FCS) program provided a focal point for much of SEDD's research, but in the 2004 presentations, FCS was barely mentioned in the SEDD overview. In past years, FCS capability goals frequently provided starting points for the flow from military needs, to technical problem definition, to motivation for specific research; but many of this year's technical presentations lacked discussion of this essential flow. This change is probably at least partially due to the Army's current focus on Afghanistan and Iraq and to uncertainties with respect to FCS procurement methods and emphasis.

The Army's decision to give the FCS's system integration contractor (Boeing) an unprecedented level of influence on the definition and development of major combat systems has the potential for great impact on SEDD. In the past, the Training and Doctrine Command (TRADOC) was the major source of requirements for new capabilities, and the Research, Development, and Engineering Centers (RDECs) were the major insertion points for SEDD science and technology. The apparent latitude in Boeing's FCS contract seems to have potential for disrupting traditional ways of establishing requirements and making technology development and insertion decisions. If this proves to be the case, it will have major impact on SEDD's fundamental business relationships with contractors and other government organizations.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

SEDD has identified some of the Army's most pressing technology needs and is engaged in a wide array of promising research endeavors focused on these needs and opportunities. For example, SEDD has recognized that improved power generation and management are essential to the reduction of logistics requirements and to realizing a wide array of important new capabilities.

SEDD is developing many important new technologies. They include fuel cells, rechargeable batteries, matrix power converters, silicon carbide (SiC) power management devices, and high-energy battery technology. Improved sensors are critical to giving lighter forces an essential edge by winning the information battle, and SEDD is deeply engaged in a multitude of efforts focused on sensor development. As evidenced by the presentation to the Panel on cold atom optics, SEDD is also addressing new developments in basic science that may provide solutions to problems of critical importance, such as underground facility detection and high-accuracy, jamproof navigation.

The radio-frequency (RF) group is to be commended for outstanding performance and clearly defined objectives that are aligned with ARL goals. The group is well known in the RF community and is highly regarded for its expertise.

SEDD's work on acoustic detection is especially impressive. The Panel and the Board commend the focus of SEDD on acoustic sniper- and mortar-location systems assembly for field units as an immediate response by SEDD to an urgent Army problem.

Opportunities and Challenges

SEDD has exceptional strength in a number of areas, including RF radar and communications, acoustic sensing, advanced sensors, and image processing.

The current resource level for the program in Power and Energy Systems appears to be inadequate to achieve the goals and roadmaps, but the earmarking of $600 million for the next 5 years for the Army's Power and Energy program is applauded. Hybrid Electric Propulsion and Power is a promising project, but issues pertaining to energy storage that may be the limiting factors for this technology (battery, flywheel, and supercapacitors) need more consideration. The Board recommends continued examination of the appropriateness of spending 6.1 (basic research) funds on the Power and Energy CTA, which is clearly development-oriented as opposed to being long-range research. This is an important issue, since 6.1 funds are generally more difficult to obtain than are 6.2 (applied research) or 6.3 (advanced technology development) funds.

In the area of fuel cells, and particularly with regard to fuel reformation, the Panel and the Board note apparent gaps within some of the projects. For example, ARL-funded research at the University of Minnesota produces a gas stream containing hydrocarbons, but none of the downstream processing deals with these hydrocarbons. Good coordination is necessary among the programs developing the components of the fuel reformation system if sufficiently clean hydrogen for the polymer electrolyte membrane fuel cell (PEM FC) is to be produced. There does not appear to be a direct connection between the fuel cell work being performed at SEDD and the work being performed at major automotive companies or at other corporations involved in fuel cell development. SEDD should proactively investigate commercial fuel cell activities and the potential for use of commercially available fuel cells for Army applications.

For the High Power Li-Ion Batteries project, more work involving cell cycling under high power conditions at high and low temperature is justified. Now that some interesting electrolyte compositions and some alternative cathode materials are available, the choices should be narrowed on the basis of the performance and life testing of cells from commercial vendors. The general methodology is appropriate, but some important variables affecting the capacity of the air electrode of the lithium (Li)/air cell are not being pursued (i.e., the porosity and pore size distribution are variables that are very likely to yield improved specific capacities). Li-ion batteries should continue to be examined in light of the focus on low-temperature performance. A clear roadmap for Li-ion battery development and deployment would be useful.

Considering the Army needs for alternating current (ac)/ac, direct current (dc)/ac, and ac/dc converters and switches of different ratings and application constraints, a valuable research project would be to seek a building-block approach that is based on the repetitive use of a limited number of module designs. Work on advanced silicon (Si)-based symmetrical devices should also be undertaken, and research and development on converters should include converters other than matrix converters.

With respect to SEDD's work on electric power systems for FCS and robotic platforms, it is important that SEDD maintain strong connections with the community at large. These connections are important because of the extensive work being done by nonmilitary laboratories such as those of the major auto companies and by agencies such as the Department of Energy (DOE).

The Panel and the Board are particularly impressed with SEDD's extremely important programs focusing on SiC-based converters, such as ac-ac mobile electric power converters and pulse converters for distributed electromagnetic armor. However, the objectives for SiC-based converters are not stretched sufficiently and should be accelerated and expanded to 200 kilowatts (kW) for all SiC-based converters by FY 2005. SEDD needs to make a full assessment of the ongoing developments by industry of SiC diodes to target only needed development areas with ARL research.

The work on high-energy lasers for directed-energy weapons is fairly limited compared with that of other services and of agencies such as the DOE. It is recommended that SEDD keep abreast of these other programs and their potential applications and adoption by the Army.

Acoustics is especially important to the Army at this time. The scope, high level of activity, and importance of acoustics would suggest that more personnel and a significant long-term investment for this area should be considered. A long-term plan of basic research to advance acoustic sensors (not just signal processing) is needed. It might start with a clear definition of what might be done with better sensitivity, better range, and other performance goals and then continue with a focus on how to get there.

Piezoelectric microelectromechanical systems (MEMS) and nanodevice research comprise an area that merits more emphasis and is related to MEMS reliability. While the group is focused on the production of working devices with specific performance goals—and robust performance is one of those goals—more specific reliability performance goals should be included, because reliability remains one of the top issues for MEMS.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

SEDD is serving the Army and the United States very well. It is responding to wartime needs in an effective and timely manner, without losing its focus on developing technologies for the Army's future. An organization that can give good presentations on acoustic sniper- and mortar-location systems that were fielded within 45 days and on something as futuristic as cold atom optics is truly impressive. SEDD is continuing to attract highly qualified scientists and engineers and to develop its infrastructure of facilities and capital equipment. The quality of SEDD research appears to be high in most areas.

As mentioned, this directorate has identified some of the Army's most pressing technology needs and is engaged in a wide array of promising research endeavors focused on these needs and opportunities. This effective focus was suggested by the discussion of SEDD accomplishments above. They include SEDD's work to improve power generation and management in order to reduce logistics requirements and to realize important new capabilities; SEDD's development of important new technologies, such as fuel cells, rechargeable batteries, matrix power converters, silicon carbide power management devices, and high-energy battery technology; improved sensors; and contributions to information warfare. Also, as indicated above, SEDD is addressing new developments in basic science that may provide solutions to problems of critical importance, such as underground facility detection and high-accuracy, jamproof navigation. While there may be a few problems with specific details of the research, it is important to recognize that SEDD is deeply engaged and generally making good progress.

The acoustic detection work being done by the directorate is impressive, and the focus on the assembly of acoustic sniper- and mortar-location systems for field units is commended as an immediate response by SEDD to an urgent Army problem. The use of acoustic impulse localization addresses a significant problem in countermortar operations in a terrorist context: that of making engagement decisions and acting on them before the enemy mortar crew disperses. It might be possible for SEDD to help with this problem by developing a real-time information display and communication system that could be kept sufficiently updated with friendly force locations and collateral-damage avoidance zones to enable timely decisions on artillery engagement and effective prepositioning or ad hoc assignment of maneuver elements for countermortar operations in areas where collateral-damage potential prevents use of artillery.

Contributions to the Broader Community

SEDD does an excellent job of coordinating its research with the broader scientific community. It has an extensive record of publication and patents, with presentations at appropriate conferences and workshops. For example, SEDD scientists and engineers were involved with and published at the Institute of Electrical and Electronics Engineers (IEEE) Microwave Week and at the Government Microsystems Applications Conference.

The status and recognition of SEDD in the community at large is reflected in the honors awarded to SEDD personnel. In the past 2 years, SEDD staff have been elected fellows of the IEEE, the International Society for Optical Engineering (SPIE), and the Washington Academy of Sciences.

RELEVANCE OF CROSSCUTTING ISSUES TO THIS DIRECTORATE

A number of projects within SEDD, such as image processing and acoustic sensing, make extensive use of computation and modeling. It would be beneficial to this directorate to expand the use of computational science and modeling. Additional modeling activities would prove useful in the development of semiconductor devices such as quantum cascade lasers and quantum well infrared photodetectors, as well as sensors, microwave and millimeter wave systems, and even fuel cell design.

Information security is relevant to SEDD in areas such as quantum cryptography and wireless communications.

The nanotechnology crosscutting initiative offers significant interdirectorate opportunities. SEDD has associated activities in molecular electronics, quantum-effect devices, and advanced materials.

5

Survivability and Lethality Analysis Directorate

INTRODUCTION

The Survivability and Lethality Analysis Directorate (SLAD) was reviewed by the Panel on Survivability and Lethality Analysis. SLAD is the U.S. Army's primary source of survivability, lethality, and vulnerability (SLV) analysis and evaluation support with regard to major Army systems. SLAD's general objective is to ensure that soldiers and systems can survive and function on the battlefield. Its mission includes the following tasks: provide SLV analysis and evaluation support over the entire life cycle of major Army systems and help acquire systems that will survive and/or be highly lethal in all environments against the full spectrum of battlefield threats; provide advice and consultation on SLV issues to Department of the Army Headquarters, to program executive officers (PEOs) and program managers (PMs), evaluators, combat developers, battle laboratories, for intelligence activities, and other Department of the Army and Department of Defense (DOD) activities; conduct investigations, experiments, simulations, and analyses to quantify the SLV of Army and selected foreign weapon systems; provide well-documented, timely technical judgments on complex SLV issues; perform special studies and make recommendations regarding tactics, techniques, or design modifications for reducing vulnerability and enhancing the survivability and lethality of Army materiel; and develop tools, techniques, and methodologies for improving SLV analysis.

Tables A.1 and A.2 in Appendix A respectively characterize the funding profile and the staffing profile for SLAD.

CHANGES SINCE THE PREVIOUS REVIEW

The major change since the previous ARL biennial assessment report is in the area of system-of-systems vulnerabilities, in which SLAD has made significant advances as described below. Since the previous report, the directorate has also, in response to specific panel recommendations, developed a strategic plan, implemented hiring initiatives, developed and implemented data management initiatives, and has been addressing insularity issues.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

The quality and understanding of the Systems of Systems Survivability Simulation (S4) software, formerly Decision Related Structures (DRS) software, have improved significantly. The articulation and implementation of the Mission and Means Framework (MMF) software, with its emphasis on mission rather than on platform survivability, are a major step forward. The MUVES-3 (Modular UNIX-based Vulnerability Estimation Suite, formerly the RIVA) is a well-managed, forward-looking approach to integrating important SLAD tools and is progressing nicely. The Target Interaction Lethality Vulnerability (TILV) software program has been developing physics-based target interaction models to be integrated with MUVES-3. The Electro-Optical Countermeasures Missile Flight Simulation Laboratory is a well-done hardware-in-the-loop simulation of an important survivability question for all (not just military) air assets.

Opportunities and Challenges

The S4 program provides a major opportunity for SLAD. The Army and the military in general need to develop or acquire appropriate tools for analyzing the vulnerabilities of system-of-systems software. Relatively little is known in this area, and much needs to be done. SLAD's opportunities are to lead the development of the technologies to do the job and to establish an Army and military-wide leadership position in system-of-systems vulnerability work. Besides being an opportunity, S4 presents a significant challenge for SLAD that will continue for many years. Monitoring this rapidly expanding area, developing requirements, leading tool development, and hiring new people with the needed skills will all place significant demands on SLAD's expertise, management, and resources.

Information assurance in the areas of commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) products may offer another opportunity for SLAD to take a leadership role in solving an important government and industrial problem.

Despite the emergence of new challenges in S4 and related areas, traditional threats are not disappearing. The Army will continue to need SLAD's world-class skills in ballistics survivability and lethality. Therefore, a second major challenge, especially to SLAD's management, will be to balance growth in the areas of S4 and information warfare (IW), information operations (IO), and electronic warfare (EW) without sacrificing its ballistics capabilities. COTS/GOTS vulnerabilities will remain a significant challenge for the near future. SLAD will continue to have workforce issues as it builds the expertise needed to meet the challenges of information assurance and system-of-systems vulnerabilities while confronting issues surrounding the aging of its workforce.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

SLAD programs and projects are well managed and clearly focused on Army needs. The scientists and engineers and managers at SLAD have a shared, clear understanding of the importance of their work and how it fits into Army plans and meets Army requirements.

SLAD continues its outstanding work in ballistics and is a world leader in this area. Overall, numerical and experimental evaluation procedures are sound, and SLAD is doing an excellent job of its conventional mission. SLAD receives high marks in its support of Army programs. One example is its Aircraft Program Support for the live-fire testing of helicopter rotorblades.

Another example of outstanding SLAD capability is the Electro-Optical Countermeasures Missile Flight Simulation Laboratory. This is a powerful representation of the strength of SLAD's mission capabilities in the area of weapons system survivability and lethality. SLAD clearly has a world-class capability in evaluating countermeasures to infrared-seeking missiles and is deeply involved in relevant U.S. programs.

SLAD is doing a good job of improving its capabilities. Specifically, it is improving the efficiency of Ballistic Research Laboratory Computer-Aided Design software, developing methodologies for including fire and blast/shock effects in vulnerability and lethality assessments, improving the MUVES model, and developing techniques for incorporating progressive degradation of weapons systems in simulations.

The Ballistics and NBC (Nuclear, Biological, and Chemical) Division struggles in the area of NBC warfare, although not from a lack of expertise or interest. The problem is a lack of resources. However, potential adversaries that either have built or are actively building offensive chemical warfare capabilities see these capabilities as an important asymmetric response to U.S. forces. Therefore, the Panel and the Board commend SLAD for keeping its NBC capabilities alive. They recommend that SLAD carefully document and highlight inadequacies in NBC vulnerability analysis at every opportunity. Such efforts will make sure that Army leadership is aware of this shortcoming and of the consequences of addressing or not addressing these inadequacies.

SLAD has struggled in recent years with the emerging and vexing area of system-of-systems vulnerability. The struggles now appear to be paying off. The directorate has developed an agent-based approach to System of Systems Survivability Simulation that it is implementing and testing. Additionally, with the Mission and Means Framework approach, SLAD has established a strong scientific basis for analyzing and understanding vulnerabilities. This approach would seem to work for both the ballistics and the system-of-systems work, thereby providing a unifying structure for the two major components of SLAD's mission. This structure had been lacking in the past.

The Information and Electronics Protection Division continues to grapple with the problem of COTS/GOTS vulnerabilities. This will remain a difficult problem, because it appears to require a great deal of vendor cooperation, which has been lacking in the past. Understanding the vulnerabilities of a proprietary off-the-shelf system presents significant challenges.

SLAD has taken significant steps to improve its visibility and to increase its effectiveness within the Army. The directorate now has a planned thrust to establish a survivability and lethality assessment role with the Missile Defense Agency. SLAD is also involved in the initial stages of Stryker, Future Combat System, Land Warrior, and Air Warrior development, though resources for this involvement are stretched very thin. Additionally, the directorate has contact with the Training and Doctrine Command related to the improvement of wargaming techniques for evaluating tactics and to the Decision Related Structures modeling work. SLAD also has a number of ongoing intramilitary collaborations, including, for example, memberships on Source Selection Evaluation Boards and the Nuclear and Chemical Survivability Committee, participation in symposia, data exchange agreements with foreign partners, and Small Business Innovation Research (SBIR) programs for crew seat protection and blast/shock analysis.

Several SLAD projects demonstrate good transition potential. The S4 program addresses a critical Army need to simulate and analyze system-of-systems vulnerabilities. The Electro-Optical Countermeasures Missile Flight Simulation Laboratory addresses an important survivability question for all air assets. MUVES-3, informed by physics-based models generated by TILV, is a central modeling and simulation capability for the Army. TILV is adding critical models, including Shock and Blast, Active Protection Systems, Military Operations in Urban Terrain, and Behind Armor Debris. Data management initiatives undertaken by SLAD will help the directorate deal with the thousands of data requests that it receives and will help leverage precious resources.

The improvised explosive device (IED) countermeasure equipment should be in the theater by September 2004. Approximately 500 of the countermeasure devices should be in theater by the end of November 2004. The U.S. Air Force has also ordered IED countermeasure equipment devices, as have several other government agencies. This program appears to be a major success for SLAD and for ARL.

SLAD also supported an Information Assurance Network Assessment of three network architectures currently deployed in theater. The survivability link cannot as yet be considered operational. However, the Panel and the Board are particularly impressed with the survivability link between SLAD and deployed units that is being established on the Secret Internet Protocol Router Network (SIPRnet).

Contributions to the Broader Community

Although SLAD is becoming less insular within the academic community, the directorate still has much work to do in this regard, especially in the area of information warfare. In the area of computer and network security, SLAD remains very isolated from the mainstream of academic work in the United States. The Panel sees signs that this is changing, but the Panel and the Board still encourage SLAD to continue deepening its contacts with the academic community and to become more involved with professional activities.

There are examples of SLAD involvement in the wider community. SLAD has built good relationships with the University of Texas at El Paso, New Mexico State University, and Texas A&M University. SLAD staff are involved in professional activities with the American Institute of Aeronautics and Astronautics, the American Society of Mechanical Engineers, and the Society for Industrial Mathematics. SLAD's professional participation in these societies is one indicator of its growing professional status. SLAD staff have also contributed presentations to the proceedings of technical conferences and symposia.

RELEVANCE OF CROSSCUTTING ISSUES TO THIS DIRECTORATE

SLAD's work is critically dependent on the validity of its models and simulations. Many of the models being developed in the TILV program and which then inform the MUVES-3 analyses suffer from a scarcity of actual physical data. Thus, verification and validation become an even more difficult problem for these models. If SLAD is going to continue to move from physical testing to modeling and simulation—and it must—it is of paramount importance that it develop methods for first verifying that codes are working correctly and then for validating that results from modeling and simulation are related to the actual, physical reality, especially when physical data are scarce and reduction to first principles is prohibitive.

Information security, especially with COTS/GOTS software, is a problem of critical importance throughout the military and industry. SLAD has an important role to fill in this area with regard to battlefield information assurance, but this is an ARL-wide issue that cannot be solved by SLAD alone.

6

Vehicle Technology Directorate

INTRODUCTION

The Vehicle Technology Directorate (VTD) was reviewed by the Panel on Air and Ground Vehicle Technology. The directorate has four divisions that are reviewed by the Panel: Loads and Dynamics, Structural Mechanics, Engine Components, and Engine and Transmission Systems. The first two of these divisions are located at the National Aeronautics and Space Administration (NASA) Langley Research Center in Virginia, and the other two are located at the NASA Glenn Research Center in Ohio.

Tables A.1 and A.2 in Appendix A respectively characterize the funding profile and the staffing profile for VTD.

The assessment detailed below reflects visits by the Panel on Air and Ground Vehicle Technology to the VTD sites at NASA Glenn (in May 2003) and NASA Langley (in May 2004), as well as the July 2004 meeting of the ARL Technical Assessment Board.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

Two major VTD programs continued to advance during the past 2 years: the Active Stall Control Engine Demonstration (ASCED) program and the Survivable, Affordable, Reparable Airframe Program (SARAP).

The ASCED program is intended to support helicopter operation in areas where airborne particulates might be encountered (e.g., over unimproved runways, in desert regions, or in combat zones). While operating in such conditions, helicopters will experience erosion of compressor blades and deposition of particulates on hot section components, even with sand separators and screens in place and operational. Both types of problem cause engine deterioration that degrades performance (efficiency) and surge margin. The loss of engine performance is undesirable because it reduces the load-carrying capacity of the machine. The loss of surge margin increases the risk that the helicopter will experience a stall/surge event and an associated and dangerous loss of a significant fraction of engine power. Research by the VTD staff has demonstrated that it is possible to detect the onset of rotating stall/surge for a combined axial/centrifugal compressor machine, and that information on such precursor signatures can be transmitted to the engine controller so that it can recognize the impending difficulty and take corrective action.

The Panel and the Board are pleased with the progress in facility enhancements, engine modifications, and experimental demonstrations in the ASCED program. The Panel has concerns, however, that the erosion-damaged engine used in the demonstration is not representative of other new engine responses (see the section “Opportunities and Challenges,” below).

The Survivable, Affordable, Reparable Airframe Program is intended to meet an important Army need—the design of helicopter fuselages and airframes so that they can better withstand battle damage. Some very good engineering and scientific research is being conducted under this rubric. It builds on accomplishments (noted in previous assessments by the Board) in composite fabrication and in crack growth in composite materials and addresses the broader, directly relevant application of allowing helicopters to withstand and inhibit the development and propagation of cracks resulting from the impact of enemy fire.

The overall quality of technical presentations of the VTD researchers in the ASCED program, in the SARAP, and generally, continues to improve and represents increasingly higher caliber each year. In addition, the Panel was pleased to note an increasing awareness within ARL that this directorate is an intellectual resource whose quality and application are continually improving. One specific highlighting of this high competency is the VTD’s strong interaction with its industry partners (e.g., Bell Helicopter, Boeing, and Sikorsky) in areas such as the SARAP and active rotor design.

Opportunities and Challenges

Mission, Organization, Funding, and Staffing of the Directorate

At the top of a list of current opportunities and challenges for the VTD is that the quality of the research produced by the VTD as a stand-alone entity within ARL could in the future be in doubt because of significant changes affecting VTD’s current mission, organization, funding, and staffing. This concern about the future of quality research is due in part to changes made by the directorate’s long-standing partner, NASA, which had set the pace for new technologies with vehicles such as the XV-15 tilt rotor, which led to the V-22. Now the NASA Glenn Research Center no longer has a rotorcraft mission and is moving away from turbomachinery, and NASA Langley is mothballing or closing structural and wind tunnel test facilities. Thus, the Army has assumed a stronger role in defining future technical objectives, and both the Army and industry are very influential in setting technology goals for future manned and unmanned vehicles. It is also the case that the Army is changing its focus in ways that spark concern among the VTD leadership about the directorate’s future relationship with the Research, Development and Engineering Command (RDECOM), as well as with an evolving NASA.

Factors that relate to concern regarding VTD’s funding situation include the following: the funding of research projects largely as procurements (e.g., ASCED and Active Twist Rotor), one-time funding decisions (e.g., reducing a basic research account fund at a university to satisfy a Department of the Army requirement), and consistent deficiencies in salary accounts. The ARL leadership has addressed

VTD's funding for full-time staff positions, but on a basis that apparently allows VTD to operate with a decreasing research staff and significant reductions in overhead resources. It is also not yet clear how the stabilization of NASA's new full-cost accounting system will affect VTD's budgetary situation. In any event, current salary and overhead inflation trends, combined with a flat or reduced mission scope, will challenge VTD's ability to maintain a quality research staff.

Discussions between the Panel and the VTD leadership during the visits to the NASA Glenn site (2003) and the NASA Langley site (2004) suggested that the VTD leadership is quite concerned about the future of the directorate. The VTD Director believes that the VTD's core competency is in rotor/structural dynamics and that its efforts in structural integrity would be dropped if the VTD continues to be financially pressed. In view of the anticipated retirements of both the VTD Director and Deputy Director, now may be an appropriate time for ARL to consider in careful detail the future of VTD. This directorate is a valuable intellectual and technical resource. It may be possible that this resource might better serve its Army clientele and continue its important technical work if its NASA Glenn and NASA Langley components were (organizationally) moved, either together or separately, into other parts of ARL. For example, some of the structural work done at NASA Langley would seem to couple naturally with the mechanics and structures work done by the Weapons and Materials Research Directorate (WMRD). This might, for example, foster synergy in preventing battle damage to helicopters and to land vehicles.

The Directorate's Institutional Knowledge

An opportunity and challenge related to those described above is occasioned by changes in senior staff, including both retirements and changes in division leadership (in addition to the changes in VTD's top management, as noted). Several senior researchers have recently retired. In the past 2 years, three new division leaders have been appointed, and many of the researchers have been replaced, generally by less-experienced personnel. This replacement of senior, experienced personnel has led to a continuing problem with the maintenance of institutional knowledge. (A related problem, which is hard to characterize, is that some individual research programs terminated when senior investigators left or retired, thereby raising questions about whether research priorities are established by the competencies or interests of available personnel.) Keeping test procedures and test results alive and repeatable or retrievable has been a long-standing concern. In many areas the technological value of tests is maintained in derived numbers that are published and stored in databases and handbooks. Similar to test procedures in materials testing, many of the procedures are documented in American Society for Testing and Materials (ASTM) Test Method Handbooks. Thus, the VTD's leadership anticipates severe data maintenance problems in testing areas such as wind tunnels and crashworthiness.

The VTD leadership feels that it is only possible to publish derived information: the "system" no longer gives credit to VTD (or ARL) engineers for producing elaborate laboratory reports, as ARL (and the National Advisory Committee for Aeronautics [NACA] and then NASA) still did in the 1960s. For example, in a Comanche helicopter tail buffet test conducted by VTD several years ago, VTD actually published the entire time-load history data on digital media. The original data for the Active Twist Rotor also still exist only in (internal, unpublished) digital form, which clearly limits their usefulness. The perceived future usefulness of such experimental data decreases if and when the derived data are first published. It decreases again when a second-generation test is performed, and it probably becomes useless when a full-scale aircraft flies successfully. However, there is a problem because, absent a means and a reward for publishing such experimental data, whole disks of old (unpublished) data lose whatever value they might still have when research staff retire.

Mentoring Within the Directorate

Another opportunity and challenge appears to be that of senior investigators providing positive opportunities for growth to younger and newer colleagues. Several senior investigators, in several areas, showed great awareness of and sensitivity to work being done in their respective research communities. On the other hand, some investigators, especially younger ones, may not be adequately aware of previous and recent work in the areas in which they are working and presenting. Helping to develop such awareness is an important part of the mentoring process.

Computational Modeling in the Directorate

One particularly important aspect of mentoring—and, indeed, of general scientific style—is the realm of computational modeling. While the computational work done at the NASA Langley site continues to improve, for example, there is still ample room for further improvements in both standards and style. Questions that should be addressed include these: Are the right computer tools being exercised? Why are general research results presented for particular numerical values of variables? Why are they not done in terms of dimensionless variables that obviate the need to repeat calculations for each individual configuration or case? Is enough attention being paid to finite elements method/finite elements analysis (FEM/FEA) mesh refinement—especially when considering cases in which scale is clearly quite important?

A strongly related concern here is the increasing dependence on FEM/FEA as a replacement for the experimental, experiential verification of analytical models. The Panel was informed of the following by VTD leadership: "The new generation of VTD technical leaders leans much harder on the researchers to develop advanced analytical methods of solving key problems and/or reducing the amount of ever-costlier experimentation. ASCED is a great example of full-level computation, and we can show similar progress in structures and aeromechanics." This is a dangerous trend on its own terms, although it may be unavoidable in certain circumstances and in view of future budget limits and uncertainties. The VTD leadership recognizes that there are limits to this approach; they pointed out that "the total validation of the dynamics of complete rotor systems still has significant weaknesses in the correct implementation of the entire physics package." Clearly, when coupled with computational practices that are less than perfect, the dangers are exacerbated still further. This is an opportune time to remind the VTD of the Army Research Laboratory Technical Assessment Board's recommendation in the previous biennial report that ARL should consider a systematic initiative to improve computational modeling across ARL.[1] As noted then, changes in computational style will become effective only when they are embraced by senior scientists and management, and when consistent and suitable mentoring of the younger scientists is implemented.

In this context, a variety of large-scale computational tools currently exist both within government laboratories and on the commercial market. As part of a computing initiative, VTD might assign to some of its capable young researchers the job of systemically identifying, securing, and coming to fully understand through comparative applications many of these large-scale computational tools for specific applications essential to ARL and pertinent to VTD. This effort would supplant trying to find new

[1]National Research Council. 2003. *2001-2002 Assessment of the Army Research Laboratory.* Washington, D.C.: The National Academies Press, pp. 32-33.

problems to do and trying to develop new computational tools. If VTD's computational experts are fully abreast of computational techniques for application to the class of materials and structures that is VTD's focus, they could become a valuable resource to the rest of ARL.

Finally, as another form of challenge, many of the managerial presentations to the Panel did not describe a clear vision and connection to the directorate's mission. In addition, many of the individual research presentations did not fully explain how the research undertaken contributed to meeting the Army's needs. The Panel has repeatedly asked for simple opening statements and/or slides that would delineate a project's goals in the context of the Army needs, but this was not regularly included as a standard presentation item.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

Potential Contributions of Two Major Programs

The ASCED program and the SARAP seem to be successfully and vigorously aimed at meeting future Army needs. Both would obviously have immediate application in environments such as those found in Afghanistan and Iraq. Good progress is being made on both programs, although further efforts, including the ones discussed below, are required before transition can occur.

The Panel and the Board are pleased with the progress in facility enhancements, engine modifications, and experimental demonstrations—although there are concerns that responses of the erosion-damaged engine used in the demonstration are not representative of responses of other, new engines. In addition, the strong interaction with industry partners (e.g., Bell Helicopter, Boeing, and Sikorsky) was also noted quite favorably by the Panel.

However, there are some concerns about further developments that are planned for the computer code, TURBO, that did not predict the experimentally observed compressor operation range extension with control. At best, a T700 case will be set up to initiate unsteady flow solution. The Panel and the Board are therefore concerned that the simulations will not make a meaningful contribution to the overall effort, and they recommend that the computational program goals be reexamined to identify how to address this issue.

Within SARAP, some good engineering and scientific research is being done on the debonding of composite skin/stringer configurations. The Board suggests that several further improvements be considered in order to improve the modeling of debonding. Convergence should be studied in the quantities of interest; it is possible that the results converge in one quantity of interest, but not in others. As an alternative, an iterative multigrid-type or composite-grid-type approach should be explored by which a fully shell model is computed to obtain a lower frequency response of the hybrid shell-three-dimensional model within the framework of the multigrid-type methods. It may be worthwhile to consider extracting stress intensity factors based on the information away from the crack tip (such as the J-integral). In this case, considerable mesh refinement is not required at the crack tip. These suggestions address both computation and the relevant physics.

Unfortunately, the related work on polymer composites caused great concern in the Panel because of its styles of computational modeling, as noted earlier. Similarly, the Panel is very concerned that two new, young, and bright researchers are working on problems that could be categorized as "long ago solved." The Panel finds it difficult to accept the rationale provided—that the work is needed to develop design tools—because current commercial codes can probably address the design issues. The Panel questions whether the senior researchers and managers have chosen wisely in assigning these projects and whether the young researchers have done an adequate job of reviewing the relevant literature and prior art.

The Panel has further technical concerns about some different aspects of the modeling of the strength of damaged composite panels and structures. The Panel and the Board suggest an examination of the following questions: Is a higher-order continuum (i.e., coupled-stress analysis) needed for such work? What does the program FLASH really do? Are adhesives such as Nomex, which was used for bonding, still used in industry (e.g., by Bell Helicopter)? What is the real value of so-called selectively reinforced, multifunctional structures? Is the potential value of the alternative being pressed (in the choice between metals versus polymeric) being oversold?

Notwithstanding the aforementioned concerns, both the ASCED program and SARAP are important efforts that are making substantial progress and give every indication that they will meet future Army needs.

Example Projects That Demonstrate Transition

The Vehicle Technology Directorate works to transfer or transition technology by disseminating knowledge and understanding about both technical information and products to engineering centers, industry, and academia. VTD works closely with the Research, Development, and Engineering Centers (RDECs) and their customers through Technology Planning Annexes (TPAs) and Cooperative Research and Development Agreements (CRADAs). From FY 2001 to the present, VTD has had eight TPAs with the Aviation and Missile RDEC (AMRDEC), the Tank-Automotive RDEC (TARDEC), and the Natick Soldier Center, some of which were renewed. VTD also established five CRADAs with industry and academia partners at Bell Helicopter, Boeing, Sikorsky, Rolands, and Polytechnico di Milano. In addition, VTD disseminates technology through various forums to organizations such as the National Rotorcraft Technology Consortium, the American Helicopter Society, and the Joint Aircraft Survivability Program Office. Such dissemination activity suggests that VTD is the aviation technology authority (with current focus on helicopters) in basic and applied research and therefore is continually sought to provide expertise in aviation technologies for the engineering centers, industry, and academia.

It is the Board's understanding that VTD receives customer funding from other DOD organizations and industry. Most important is VTD's well-established relationship with the National Aeronautics and Space Administration through an overarching Memorandum of Agreement and local Center Operating Agreements at the NASA Langley and NASA Glenn Research Centers. Although no money actually changes hands, these agreements have had a synergistic effect in the past, allowing both the Department of Defense and NASA to leverage dual-use technology.

The Panel is also directly aware of two projects that are in various stages of transitioning into meeting daily Army needs. One of these is the work on the development of high-temperature ceramic composite combustor liners to replace their metallic counterparts in gas turbine engines. The ceramic liners weigh less than one-third of their metallic counterparts. In addition, since these ceramics can sustain higher temperatures than metals can, less energy is wasted on cooling the combustor linings.

The second VTD project that shows transitional promise is one that the Panel did not formally review, namely, the Icing Research Tunnel, which is used to evaluate the effects of icing on full-size aircraft components or on models of aircraft. The facility can simulate real-time flying conditions and is in such high demand that it must be reserved more than a year ahead of its planned use.

Support to the Troops in Iraq and Afghanistan

VTD has not been directly connected to any current projects in either the Iraq or Afghanistan theaters, but it does consult for Fort Eustis, Virginia, which provides the first line of fleet support in aviation. Moreover, the ASCED program clearly is aimed at a serious problem endemic to those theaters, so VTD's continuing good efforts on that program will produce practical, useful results at some point.

Contributions to the Broader Community

By and large, VTD has continued to reach out to the broader professional community. Most notably, researchers continue to present papers at appropriate conferences and to publish significant numbers of papers in proceedings of meetings and in the major journals in the VTD disciplines. From January 2001 through July 2004, VTD staff contributed 169 papers to presentations and proceedings, 95 refereed journal articles, 67 technical reports, and 21 patents.

VTD research staff members are active participants in a variety of professional societies (e.g., the American Helicopter Society [AHS] and the American Institute of Aeronautics and Astronautics [AIAA]). Several hold offices on committees and boards within these societies, organize conferences, and otherwise actively participate. The VTD leadership and staff also actively participate in a variety of outreach activities (e.g., to Historically Black Colleges and Universities) and conduct a variety of events with nearby kindergarten through 12th-grade schools.

Many of the VTD staff have been recognized by their professional communities by being invited to present papers and lectures and having earned "Best Paper" awards. Other honors include earning prizes and recognition from societies (e.g., appointment as associate fellows and fellows of AIAA and AHS), as well as earning promotions and awards from NASA and from ARL.

RELEVANCE OF CROSSCUTTING ISSUES TO THIS DIRECTORATE

Some groups within VTD have performed computational modeling in styles and to standards consistent with the best professional practices. However, there continue to be substantial instances in which researchers and investigators have not properly considered the following:

- *Verification* (i.e., that a computer program does what it was intended to do);
- *Validation* (i.e., that the computer program produces results that are valid in and relevant to the domain in which it was intended to operate);
- *Use of a variety of standard operating practices for doing calculations and presenting results* (e.g., the use of appropriate dimensionless variables); and
- *The consequences of the widespread replacement of experiments by computational modeling* (e.g., see the discussion on computational modeling above).

There were no issues raised during the VTD reviews that directly concerned information security. However, as indicated above, concerns were raised about the maintenance of data and of institutional knowledge.

VTD works closely with other directorates in ARL, mostly with the Weapons and Materials Research Directorate in structures technology and with the Survivability and Lethality Analysis Directorate (SLAD) concerning aircraft survivability. There is technical expertise within VTD that could be applied in support of other missions of other ARL directorates (e.g., fostering synergy with WMRD in preventing battle damage to helicopters and to land vehicles). The SARAP effort, for example, could be of interest to WMRD and might benefit from interaction with WMRD staff. However, the Panel is not aware of any active interdirectorate activities relating to this program.

Given the division of VTD between two disparate geographical sites (NASA Glenn and NASA Langley) and different mission flavors (turbomachinery and rotorcraft engines at NASA Glenn, and crashworthiness and rotorcraft blades at NASA Langley), it may be useful to consider opportunities for connectivity between VTD-Glenn and VTD-Langley, and with the Army Research Office (ARO), as being a form of interdirectorate activity. Such connectivity and interaction were reflected in some innovative work on ceramic thermal and environmental barrier coatings and crack propagation, and on scales and available tools.

Because of the importance of the enabling high-temperature material technology, the connectivity issue for the thermal and environmental barrier coatings efforts at VTD-Glenn has been well addressed through extensive collaborative research for expanding coating applicability and promoting technology transfer. Research and development of coating technologies have been integrated through various government, university, and industry programs, including an Army CTA Propulsion and Energy program aimed at developing durable ceramic environmental barrier coatings for Si3N4 engine components.

Several university research programs have focused on fundamental aspects of the coating behavior, including among them Princeton and Pennsylvania State Universities. Strong government-industry partnerships have facilitated the development and commercialization of the thermal and environmental barrier coating technologies, with General Electric Aircraft Engines (GEAE) and Pratt & Whitney both being involved in processing and evaluation of coating systems. Combustor rig tests of low-conductivity thermal barrier coating on hardware components by GEAE were successfully completed and demonstrated in a NASA Ultra Efficient Engine Technology diagnostics test on a deflector and in a DOD Integrated High Performance Turbine Engine Technology test on a combustor liner. The coating systems are currently being evaluated by GEAE for potential use in production engines.

Pratt & Whitney has been involved in electron beam-physical vapor deposited (EB-PVD) processing optimization, burner rig testing, and erosion evaluation of several low-conductivity turbine airfoil systems. The advanced turbine airfoil low-conductivity coating systems are also being considered for further development for future pulse detonation engine-based, constant volume combustion cycle turbine hybrid engines.

VTD conducted a Technical Interchange Meeting at VTD-Langley to address a concern that had been previously expressed by the Panel about connectivity between Langley and Glenn on fracture mechanics (crack propagation) research. At the Technical Interchange Meeting, it was concluded that fracture mechanics research at the two sites is significantly different, each having its own specialties and unique thrusts. However, the VTD researchers did agree to conduct yearly coordination meetings in order to update research, exchange publications, and review the potential for collaboration.

7

Weapons and Materials Research Directorate

INTRODUCTION

The Weapons and Materials Research Directorate (WMRD) was reviewed by the Panel on Armor and Armaments. The directorate was formed in 1996 by the merger of the Materials Technology Laboratory and the Ballistics Research Laboratory, which had been independent directorates prior to the formation of the Army Research Laboratory (ARL). Most of the WMRD staff and facilities are located at Aberdeen Proving Ground (APG), Maryland, with additional research cells located at the ARL complex in Adelphi, Maryland, and at ARL Centers of Excellence at the University of Delaware, Johns Hopkins University, Rutgers University, and the University of Massachusetts at Amherst.

WMRD has three divisions that are reviewed by the Panel: Materials, Terminal Effects, and Ballistics and Weapons Concepts. In addition, WMRD includes the ARL Robotics Program Office and the Army Electromagnetic Gun Program Office. WMRD also is responsible for the Robotics Collaborative Technology Alliance (CTA).

Tables A.1 and A.2 in Appendix A respectively characterize the funding profile and the staffing profile for WMRD.

CHANGES SINCE THE PREVIOUS REVIEW

WMRD is about the same size in both personnel and budget as it was at the previous biennial review. A major improvement in effectiveness has been achieved by filling nearly all of the acting branch chief positions with permanent appointments.

The Materials Division recently has been reorganized into four branches:

- *The Multifunctional Materials Branch* works chiefly on nanomaterials, polymers, elastomers, and electronic materials. The bulk of WMRD's basic research (6.1) funding for materials is allocated to this branch.
- *The Survivability Materials Branch* focuses on lightweight armor, advanced materials for armor, and mitigation of vehicle ballistic shock.
- *The Ordnance Materials Branch* focuses on penetrator materials, high-gravity physics of failure, gun-projectile material interactions, and electromagnetic gun materials.
- *The Materials Applications Branch* works on corrosion engineering, failure analysis of components, signature-reduction materials, cost modeling of materials, pollution reduction, and advanced manufacturing methods.

According to the division Chief, this reorganization was performed to make the branches more customer-focused and to break up some concentrations of personnel that had been based on place of previous employment.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

Remarkable advances have been made in the development of a blast-deflection, active protection system that will protect the Future Combat System land vehicle against a number of threats. This development is nearing the stage at which a number of its critical components can be field-tested. This system is discussed below in more detail.

The Panel and the Board consider the electromagnetic armor effort to be a real gem within the ARL's program. The theory and computational work that ARL has brought to this problem is a good example of how developmental research is most effectively done. By developing its own computation models, the team was able to get to the heart of the physical issues in a way that is hard to accomplish with a large and general type of code. Understanding of the underlying physics governing the electromagnetic disruption and breakup of metal shaped-charge jets appears to be well in hand. Both analytic and numerical models have been developed, are providing a sensible solution of induced instability growth and material dispersion, and have been subjected to some experimental validation. Further verification and validation studies are certainly encouraged to support further development and to provide confidence in the numerical codes and models. Interactions with workers on the Sandia National Laboratories Inertial Confinement Fusion program or the Lawrence Livermore National Laboratory's National Ignition Facility, where similar issues are being investigated, could prove fruitful.

A computer code has been developed for the prediction of the failure of fibrous composite materials under high-rate loading conditions. The model, based on a continuum mechanics-based description that involves more than 30 material parameters to be determined from experimental measurements, gives quite good predictions for the difficult problem of failure due to the oblique impact of a projectile on a laminated plate. The marketer of a major finite element code has made the computer code available commercially. In its present form, the model appears to be limited to small deformations.

Two major opportunities to use materials technology as an enabler to advance the warfighting capability of the soldier are discussed in more detail below: (1) the development of a process to produce phased-array antennas from thin-film dielectric materials and (2) permselective membranes to replace bulky and expensive chemical protective suits now worn by the soldier.

Other developments that have been transitioned to service are the following:

- A modular artillery propellant charge system;
- A barrel-reshaping process to improve the accuracy of 120 millimeter tank cannons after extensive service;
- A water-dispersible polyurethane chemical agent-resistant coating made available to paint vendors; and
- A new formulation of polymer resin that will reduce the styrene emissions in the fabrication of polymer matrix composites.

Opportunities and Challenges

Progress similar to that made in active protection systems and electromagnetic armor has not been made at the same rate in developing light-armor systems for vehicles and for personnel. This is, by nature, a more difficult problem than the above weapons systems. In this area, close coupling between understanding the physical modes of armor failure through experimentation and realistic modeling of the failure event is crucial. Better integration of the mechanics- and materials-oriented research staff is perhaps called for.

The staff of WMRD is to be commended for their efforts to achieve a better balance between experimentation and modeling. This has certainly been achieved by the mechanics-oriented staff, but among the materials-oriented staff there is an opportunity to enhance their research by greater use of modeling. This is not necessarily a call for greater use of complex quantum mechanical models, although they certainly have a role in modern-day materials science. However, with the wealth of modeling talent available in ARL generally and in WMRD specifically, the opportunity exists for extensive in-house training.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

The technical program of WMRD is uniformly high in quality, and the work seems focused and relevant to the Army's needs. The speakers making presentations to the Panel tended to communicate well within the expected style, which tends toward overly colorful and busy viewgraphs. Added to this propensity is a real pressure, in such briefings, to communicate the message that "a lot of things were done," rather than to tell a clean technical story. Also, the uniformity in viewgraph, poster, and presentation style suggests that a significant amount of coaching took place before the briefings. While this is not all negative, it should be recognized that every element of imposed control has an associated cost. In a research environment, freedom of expression and creativity produce large rewards. It may be better to allow a bit more personal latitude at the expense of losing the united front. However, one form of uniformity that the Board would appreciate would be the inclusion in every presentation of the level of personnel and funding devoted to each project since its inception.

The management of WMRD continues to be very responsive to the suggestions for improvement provided by the Panel. For example, in the previous biennial report, the suggestion was made to include the plug shear failure mode in the composites analysis software. This year, it was part of the software package that has just been completed and marketed to the public. The staff appear to have taken to heart the suggestion that modeling should be proven out by experimentation. They have worked hard to balance the presentations with laboratory tours and poster sessions.

The Panel and the Board agree that WMRD's high level of partnership with universities is good, and it is a hallmark of the research done within the Materials Division. However, it was often hard to appraise ARL's contribution versus that of the university or contractor to the overall progress of the various projects. This was due in part to the way that the contributors were credited, by listing all contributors at the end of the talk. A more thorough breakdown of credit would make this aspect clear.

Examples of WMRD's contribution to Army needs include the following:

- Development of thin-film dielectric materials,
- Research on active protection systems,
- Transitional work in permselective membranes, and
- Direct assistance to the troops in Iraq.

Thin-Film Dielectric Materials Development

Previous research had developed a powder processing route for making barium-strontium titanate (BST) components for phase shifters at a price low enough to allow consideration of the replacement of all communications antennas with this technology. However, scale-up work showed that the bulk components required too high a power level to be operationally economical. Therefore, attention was focused on making the phase shifters with thin films of BST.

The advantages of a phased antenna are that it provides a greater range of communication across multiple communications systems from 20 to 45 gigahertz with high data rate capability. This capability results in a highly mobile communications system for the digital battlefield of the future. An important additional advantage is that it provides increased survivability to the communications command centers because of the low profile of the antennas. The major obstacle to this system development has been the high cost of antenna components made from ferroelectric materials. To make this development economically feasible to the Army, the cost per installation must be reduced from several hundreds of thousands of dollars per vehicle to tens of thousands of dollars. This is an excellent example of a case in which materials science and engineering can provide an enabling breakthrough.

Through substantial team effort, a process has been developed for producing magnesium doped BST thin films using a metal-organic solution deposition technique. Careful studies have been made of microstructure, surface morphology, interface bonding, and dielectric and insulating properties. The manufacturing process appears to have appropriate economics, although not much was revealed about this during the presentations to the Panel. Meticulous tests were carried out with respect to tolerance for high vibration (fatigue failure), shock, stress, and elevated temperature (thermal fatigue). The experiments seem to have been well planned and carried out. However, there was a distinct absence of any use of modeling to guide the direction of the research. The Panel suspects that more attention to modeling might have advanced the progress of this important program. For example, some modeling might have pointed out that the approach originally applied to making monolithic components would have been limited by power (high voltage) considerations.

The progress reported on thin-film dielectric materials development was very encouraging. However, one problem remains before the phased arrays can be field-tested. Thin films are notorious for problems with residual stresses being built in during fabrication, and this system is no exception. Residual stresses as high as 2 GPa have been measured. These stresses lead to the formation of voids and cracks, with failure of the structural integrity of the array. Careful measurements of residual stress are being made, and these are being correlated with processing conditions. It is expected that, with further work, the residual stress problem can be minimized.

Active Protection Systems

Active protection systems are armor systems that intercept a threat before it hits a vehicle. Active protection is an absolute necessity for the Future Combat System, since that system cannot carry sufficient armor to defeat a number of threats, especially the tank-fired, long-rod kinetic energy (KE) penetrator. Because antitank KE rounds move at such high velocities, the time line for sensing, engaging, and neutralizing an incoming KE penetrator is less than 1 second. An active protection system is made up of the following components: threat warning sensors, a tracking and fire control component, a countermeasure launcher, the countermeasure, and base armor.

Although various active protection systems have been examined, the focus at ARL has turned to blast deflection. A high-explosives warhead countermeasure is launched to intercept, at some appropriate engagement distance, the incoming KE threat. Detonation of the warhead generates a blast that loads the KE projectile and causes it to swerve and miss the vehicle. Pacing technologies can be divided into two primary categories: KE projectile tracking and blast deflection. KE projectile tracking challenges include issues related to sensor sensitivity, accuracy, speed, and cost, combined with the complexity of the projectile signature. The challenges for blast deflection include warhead design, creation of the proper blast loading, detonation timing, accuracy, and the available time line.

The active protection system work is a well-managed program that has used a suite of analytical and computational tools, combined with well-planned experimentation, to understand, bound, and develop solutions for the various technical challenges. The researchers have developed enabling technology for KE threats that is robust against a variety of KE long-rod projectiles. Further, they have demonstrated the technology against some chemical energy (CE) munitions. Although the time line is considerably less stressing for CE munitions because of their lower velocities, other issues, such as detecting and tracking CE munitions and their very different geometric profiles, result in other challenges. Current efforts are focused on integration of the active protection system onto the vehicle (considerable progress has been made) and further research to improve the effectiveness of the warhead countermeasure (e.g., its size and weight).

Permselective Membranes

The work on permselective membranes is a materials science effort that is in transition from 5 years of basic research to an applied development of chemical/biological protective clothing. This project typifies the important role that WRMD provides in applying fundamental research to protect the warfighter. Traditional material screening methods were appropriately used to determine permselective membranes to meet a near-term solution for protective clothing. Long-term concepts also have been envisioned. Although it was suggested that this concept may be effective for chemical protection from mustard agents, additional work that is being carried out needs further study to demonstrate effectiveness against a broader class of chemical agents.

Much of the current focus of the work on permselective membranes appropriately centers on material processing and commercialization issues. The directorate's good ties to commercial partnerships and university research can strengthen this effort. However, there is some uncertainty about the level of interactions and collaborations that the ARL team has with their colleagues at the Natick Soldier Systems Center. The Board suggests that these ties should be reestablished and strengthened.

Assistance to Troops in Iraq

A wealth of knowledge concerning ballistics, weapons systems, and materials resides in the WMRD staff. This expertise has been used effectively when called upon for "quick fixes" to problems that have arisen in Iraq. For example, WMRD staff provided a quick fix to prevent enemy troops from disabling the Abrams tank by shooting up its tailpipe. Another quick fix was to devise and manufacture several hundred armored doors for the High-Mobility Multipurpose Wheeled Vehicle (HMMWV, or Humvee).

Contributions to the Broader Community

WMRD is well connected to the Army Research, Development, and Engineering Command, which forms the directorate's main customer groups. Each year the directorate holds an off-site planning conference to learn about the needs of these customers and to discuss their plans for future research. These conferences have been highly successful and should be continued.

WMRD, and in particular the Materials Division, maintains a high level of partnerships with universities. Most of these involve near-weekly interactions with the particular university group. Similar close connectivity with the Sandia National Laboratories and the Los Alamos National Laboratory in dynamic modeling was not emphasized or demonstrated.

While in past years WMRD has shown good and improving metrics dealing with issues such as papers published, presentations, professional society activities, and educational outreach, no information of this type was received at the 2004 review. The Panel and the Board recognize the heavy workload imposed on WMRD staff as a result of the Iraq conflict and the pressures brought about by the Future Combat System. Nevertheless, it is increasingly important for research staff to improve and document their professional credentials.

8

Nanotechnology

INTRODUCTION

Charge to Review Team and Review Process

The Nanotechnology Review Team, assembled at the request of the ARL Director, met in May 2004 at Aberdeen Proving Ground, Maryland, to conduct a crosscutting technical assessment of programs within the Army Research Laboratory (ARL) relating to ongoing efforts in the field of nanotechnology. That was the first year that such a review had been conducted.

The review covered activities from multiple ARL directorates, primarily the Weapons and Materials Research Directorate (WMRD) and the Sensors and Electron Devices Directorate (SEDD). The reviewers focused on the overall quality of the efforts and on the integration of those efforts both among themselves and with other ARL objectives. The review included 18 separate presentations covering approximately 30 individual projects, a poster session and laboratory tour, and a significant dialogue between the reviewers and presenters. The eight review members, drawn from existing panels of the Army Research Laboratory Technical Assessment Board, represented a composite of academic and industrial expertise.

What Is Nanotechnology and Why Is It Relevant to the Army Research Laboratory?

Unlike most other technological areas, nanotechnology is new, both in terms of ARL experience and in terms of being a recognized engineering and scientific discipline. Consequently, for this report a usable definition, taken from the National Nanotechnology Initiative's (NNI's) Web site (http://www.nano.gov/html/facts/whatIsNano.html), defines nanotechnology as having three required components:

1. Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range.
2. Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.
3. Ability to control or manipulate on the atomic scale.

The consensus working definition presented by ARL is as follows: "Nanotechnology is seeing properties that you do not see in bulk."

ARL's rationale for involvement in such technologies was explained to the Review Team as being derived from the following statement of the Army's vision: "The Army must provide combat commanders with agile, versatile, and strategically responsive forces, completely integrated and synchronized as members of the joint interagency team and with the Army's coalition partners." An additional element of its rationale is that ARL needs to invest in opportunity-driven research that leads to revolutionary change, focusing in particular on technology innovations that provide smaller, smarter, lower power, and lighter support for fighting forces. Nanotechnology, by contributing to reductions in the size of devices and/or by providing new material characteristics, is deemed by ARL to have the potential for such revolutionary change.

Nanotechnology Within the Army Research Laboratory

Nanotechnology within ARL is currently not a program per se, but a rubric applied to a set of projects across multiple directorates, primarily SEDD and WMRD. Nanotechnology does not currently have a designated technical or program lead or any formal organized leadership team. There are, however, two relatively new institutes with direct relevance to nanotechnology formed under Army and ARL auspices:

- The Institute for Soldier Nanotechnologies (ISN) was formed in 2002 at the Massachusetts Institute of Technology for the express purpose of "using advanced nanotechnology research to dramatically improve the survival of the soldier of the future" (http://web.mit.edu/isn/).
- The Institute for Collaborative Biotechnologies (ICB) was formed in 2003 as a consortium of academic and university partners to "provide the Army with core competencies and expertise in the area of biologically-derived and biologically-inspired materials, sensors, and information processing expected to impact applications in precision strike, signature management, chemical/biological, and particulate environmental protection, and counter-terrorism capabilities" (http://www4.army.mil/ocpa/read.php?story_id_key=5170).

The review presentations included brief overviews of both of these institutes, but no representatives from either was present, nor was there any presentation of details of projects or their results.

The approximately 30 identifiably separate projects that were presented for review are being performed or led directly by ARL staff. They fall into one or more of four nanotechnology areas:

1. *Nano devices and sensors*. These artifacts are constructed from nano-size materials and can be assembled into larger subsystems to perform certain specific functions, especially involving either computation or sensing. Of the approximately 30 projects, 8 focus on nanotechnology.
2. *Nano materials*. These materials are designed to leverage molecular-level properties in order to achieve specific higher-level material properties. Projects in this area are of two types: those

close to classical materials sciences or metallurgy, and those representing new ways of thinking about materials. Of the approximately 30 projects, 8 focus on nanomaterials.

3. *Bio-nanotechnology*. Such artifacts and materials have their origins in biomolecular structures. Of the approximately 30 projects, 2 focus on bio-nanotechnology.
4. *Computational nanoscience*. Computational nanoscience uses advanced modeling and high-performance computational techniques in support of nanotechnology research. Of the approximately 30 projects, 5 have this as a focus.

A few areas of nanotechnology, such as quantum computing, do not fall into any of the four categorizations above and are not posited at this time as being of key relevance to ARL's mission.

In terms of technical expertise, the ARL in-house researchers interviewed by the Review Team constituted a healthy mix of new employees fresh out of graduate school and more senior personnel. In the latter case, there was a significant mix of researchers who had stayed within their base discipline and those who had "crossed over" to a new nano area.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

The following list summarizes some specific project results that the Review Team concluded are particularly significant, either to the Army and ARL's mission or to advanced science in general. These results are mentioned here because they reflect advances reported in the reviewed presentations, regardless of how well they fit within the definition of nanotechnology provided above.

- Demonstrated improved infrared sensor devices using quantum wells,
- Higher-power infrared lasers using quantum wells with world-record efficiency and power,
- Nano-magnetic resonance imaging (MRI) instrumentation that allows structures at the molecular scale to be observed and properties to be measured,
- Demonstrated single-molecule switch with memory characteristics,
- Development of nano-size magnetic particles that can be embedded in adhesives, and
- Development of nanocrystalline tungsten to replace depleted uranium.

Opportunities

In general, nanotechnology offers the Army at least two major opportunities. First, with a good systems focus, nanotechnology can potentially provide revolutionary advances in capabilities in support of the soldier in the field with respect to the following: what the soldier wears and carries, how it interacts with the battlefield environment, direct interactions with a networked battlefield, and reduction in the logistical tail. Second, nanotechnology can change the way that such systems are fabricated, from a top-down system integration to a bottom-up self-assembly of material by design.

Challenges

In a nascent and wide-open field such as nanotechnology, it is clearly difficult to decide what is both good science and relevant science. Answering questions in these areas represents the core of the challenges facing ARL as it moves forward in nanotechnology. In general, as indicated above, the material presented to the Review Team was in itself not a nanotechnology program so much as a series of disconnected projects. Some of these, although quite good technically, did not really fit within the scope of nanotechnology as defined by the NNI (see above) and conventional scientific usage. In particular, the challenges facing ARL in this area include the following:

- *Developing the key themes that would help identify areas of most impact for ARL nanotechnology work.* As a side effect, the development of these themes will help ARL to crystallize its definition of nanotechnology and to clearly identify those projects that are nanotechnology in the most broadly understood sense, as opposed to those that are most properly advanced materials science (not nanotechnology, but still clearly in ARL's interest to pursue).
- *Integrating a sufficient systems engineering approach into the individual projects so that a bridge or roadmap to gains in warfighter needs can be rationally drawn.* Such integration would help to identify nanotechnology areas of most relevance to the ARL mission and those key metrics that over time will show progress toward deployable technologies.
- *Deciding on an appropriate structure for a nanotechnology program.* This structure could be developed from the current relatively disconnected set of projects, perhaps through a steering group, to a Collaborative Technology Alliance such as is done now by ARL for other technologies.
- *Developing an appropriate mechanism to engage with the Institute for Soldier Nanotechnologies and the Institute for Collaborative Biotechnologies.* The purpose of this mechanism would be to ensure transfer of results and a continued focus by these institutes on problems of relevance to Army missions.
- *Fostering the right level of collaboration between ARL projects and with the outside world.* This effort would avoid either duplication of work being done by bigger extramural groups or missing areas that are of unique relevance to the Army.
- *Ensuring that the more established ARL researchers who are moving into the nano arena from more traditional disciplines can function at a productive level.* Sabbaticals, nanotechnology "boot camps," and sponsorship of visiting scholars to work in the departments of these researchers may be appropriate.
- *Enhancing collaboration between theory, modeling, and experimental verification to leverage the unique and often world-class ARL infrastructure and thereby accelerate the transition time from new concept to potential deployment.*
- *In the devices area, ensuring that the silicon roadmap for the next 15 years is well understood, including the dark corners where significant problems lie.* Such an understanding can help ARL to avoid projects that do not materially advance beyond characteristics projected in the silicon roadmap. Perhaps more importantly, for those nanotechnology device technologies that do offer advantages, it will be important to understand a technology's true potential and especially what is needed for it to grow from a demonstrated device to a full system. Such an understanding may require specific and unique ARL work—in the context of soldier systems—on elucidating key environmental effects, new fault models, new potentials for redundancies, and ways to connect with classical systems. Many of these latter questions are not being addressed by the current nanotechnology community, but they will be essential for turning the technologies into robust opportunities.
- *In the materials group, determining how to avoid upsetting currently highly successful classical efforts while providing key intellectual and modeling infrastructure to support increasingly molecular-level focus.*

- *In the computational modeling area, ensuring that nanotechnology researchers are aware of and have access to the most appropriate externally available modeling tools, thereby freeing ARL computational scientists to work in those areas using capabilities currently unavailable to them.* This challenge includes in particular identifying existing software tools, especially public domain tools, that may carry over directly to problems of ARL interest. The goal is to avoid duplicating existing modeling capabilities and instead to work toward enhancing such capabilities in support of new research. Making such enhancements available to the greater research community through re-release via common public domain licensing should thus be considered an additional measure of research effectiveness.
- *Developing an appropriate level of in-house domain expertise to handle the bio-nanotechnology area, especially in sensors areas that are unique to Army applications.*
- *Integrating fuel cell work with larger Army and commercial projects and ensuring its relevance.* This challenge includes, in particular, reviewing the goals of the ARL research in terms of what is needed in the field, and comparing the end optimizations developed at ARL with other approaches developed elsewhere in the Army and in the commercial arena.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

It is clear that nanotechnology has the capability to contribute to the Army's needs, both in the near future and in the longer run. Examples of such contributions to date include the following:

- *The development of approaches to design additives that affect the molecular surface of resins to aid in materials with decontamination and/or sensing capabilities.*
- *Faster curing of induction-processed adhesives using nanomagnetic particles in the adhesives.* Such capabilities would both decrease the downtime of equipment in the field and increase the productivity of limited numbers of maintenance personnel.
- *The demonstration of improved infrared imaging sensors with increased resolution and reduced blooming for night-vision applications.*
- *The defeat of shoulder-launched missiles by focusing high-power infrared lasers on them.* Such threats are of continuing and perhaps growing significance, as recent events at the Baghdad airport demonstrated. They may become of growing importance at domestic airports as terrorists attempt to use such weapons against commercial air traffic.
- *The development of nanocrystalline tungsten to replace depleted uranium in penetrating shells.*
- *A handheld protein microarray capable of detecting up to four biological agents in a water sample on one test ticket.* (For additional information, see http://www.rdecom.army.mil/rdemagazine/200402/index.html).
- *An Agentase Nerve Agent Sensor*. This sensor is a polymer embedded with an enzyme that changes color in the presence of sarin nerve gas; this sensor has been transferred to a new company.

Contributions to the Broader Community

Given the early state of nanotechnology development, it is not surprising that both the nanotechnology community as a whole and the specific ARL community are still formative in nature.

Consequently, it is a bit more difficult to judge overall contributions to the broader community than for many other areas of technology. However, the review did touch on three metrics that are of relevance: written records, academic interactions, and technology transfer.

While information on papers and presentations was not made available for all of the projects included in presentations to the Review Team, it is clear that such external review and exposure are important to the ARL technical community, and are an integral part of many projects. Further, given the relatively short time that some of the more energetic ARL researchers have been at ARL, it is not surprising that the key publications cited for many of the projects predate the researchers' employment at ARL.

It is also clear that academic partners are equally important to the ARL nanotechnology effort, but with somewhat bimodal levels of interaction. For the 30 reviewed projects, 12 of them identified a total of more than 33 distinct academic partners and the rest had none. In many cases, the interaction seemed to be that of a typical grantor-grantee relationship. In several others, however, especially if the physical distances between ARL and the institutions were short, the interactions seemed extraordinarily active, with the sharing of laboratory and experimentation occurring on an almost daily basis, even when there was no formal contract vehicle. Given the world-class state of much of ARL's facilities, the Review Team encourages such interaction.

In terms of technology transfer, there were signs of significant activities. Several of the projects have reported patent applications and significant activities under Cooperative Research and Development Agreements. About half a dozen start-up companies and spin-offs were also identified, although this was not uniform across the projects. In addition, on February 3, 2004, ARL and the Maryland Technology Development Corporation co-hosted a showcase, "Providing a Competitive Advantage Through Innovative Nanotechnology," geared toward small businesses and entrepreneurs. It should be repeated at regular intervals. (For additional information, see www.rdecom.army.mil/rdemagazine/200403/part_arl_showcase.html.)

RELEVANCE OF CROSSCUTTING ISSUES

All three of the crosscutting issues (modeling and simulation, information assurance and security, and interdirectorate activities) identified in Chapter 1 of this report find relevance within ARL's nanotechnology activities. The strongest relevance is with the issue of coupling modeling on ARL's high-performance computing facilities with experiments. Having models with strong experimental verification is at the core of making ARL's work in nanotechnology not only relevant but also truly valuable and unique. ARL's robust laboratory facilities enhance this potential capability, and a conscious effort to promote such coupling should be encouraged.

ARL's nanotechnology arena does not at this time have information security issues in the sense applied to the other program areas. However, there are interesting and unique future issues that are worth ARL consideration. For example, when future soldiers are literally wrapped in nanotechnology systems, security issues will include protecting them against outside influence and ensuring that such systems cannot easily be used by hostile forces.

Previous chapters of this report have addressed the relevance of crosscutting issues to specific ARL directorates. Nanotechnology is, of course, a crosscutting area. The Review Team characterizes nanotechnology generally, and within ARL, as currently heavy on science and weak on applications and demonstrable milestones. The Review Team and the Board judge this state of affairs to be appropriate at this time but likely to change.

9

Robotics

INTRODUCTION

Robotics research and development R&D at ARL is focused on semiautonomous navigation for small and medium-sized vehicles. The R&D has four components: (1) *Perception* refers to the mechanism by which a robot senses and perceives the environment. (2) *The control function* takes perpetual features and translates them into actuator actions (e.g., acceleration, braking, and turning) that control vehicle navigation. (3) *Robot supervision* is an aspect of a semiautonomous vehicle system that allows a human operator to intervene and take control of the vehicle if required. (4) *Mission packages* refer to end-user applications for which autonomous robots are being developed. As presented to the Robotics Review Team, the focus of ARL's robotics activities is the development of semiautonomous ground vehicle technologies to support operations and provide situation awareness capabilities in the battlefield.

One of the goals of the robotics activities is to achieve control of many robots by one or a few humans. That goal is addressed by human workload measurement, important to ARL experiments. The Board believes that this goal will not be achieved soon. As soon as mission requirements are considered, the personnel needed to manage each robot's activities escalate. For a reconnaissance mission, for example, the sensory output is intended for the benefit of human observers, and the routing of the information obtained by the robot must be managed interactively. For targeting, it will be a long time before human verification is not required. Perhaps a more feasible near-term goal is single-operator management of several Multifunction Utility/Logistics Equipment (MULE) robots.

The Robotics Review Team, assembled at the request of the ARL Director, met in May 2004 at the Army War College to conduct a crosscutting technical assessment of programs within the Army Research Laboratory (ARL) relating to ongoing efforts in the field of robotics. That was the first year that such a review of the ARL robotics program had been conducted.

The review covered activities from multiple ARL directorates. The reviewers focused on the overall quality of the efforts and on integration of those efforts among themselves and with other ARL objectives. The review included presentations of technical projects, a live demonstration of field robotics, and a significant dialogue between the reviewers and presenters. The Review Team members, drawn from existing panels of the Army Research Laboratory Technical Assessment Board, represented a composite of academic and industrial expertise.

The review was hosted by the Weapons and Materials Research Directorate (WMRD), which also manages the Robotics Collaborative Technology Alliance (CTA). The Review Team was briefed on a broad array of ARL robotics activities. The briefings were organized into six components: technology demonstrations, program overview, research in perception, research in intelligent control, research in human-robot interfaces, and research pertaining to mission packages. The ARL in-house presenters represented more than 60 ARL staff members and several contractors and collaborators from the CTA. The ARL robotics projects presented to the panel are supported by more than $20 million per year of research funding.

ACCOMPLISHMENTS AND OPPORTUNITIES

Most Significant Advances

The Robotics Review Team considered the technical quality of the ARL core robotics research to be high. Indeed, much of it is competitive with state-of-the-art, world-class research in applied robotics. ARL has produced three notable ground vehicle robot platforms: the Soldier Unmanned Ground Vehicle (SUGV), the Multifunction Utility/Logistics Equipment (MULE), and the Armed Robotic Vehicle (ARV). ARL developed the Experimental Unmanned Vehicle (XUV) as a testbed to assist in the development of autonomous navigation technology. The SUGV is a small portable robot vehicle designed to provide situation awareness data to the soldier. The MULE, the “soldier’s pickup truck,” is a larger semiautonomous vehicle designed to follow (in some cases precede) and support the dismounted soldier at low speeds. The ARV is a larger (approximately 9 tons), smarter, and faster robot vehicle designed with more advanced navigation and perception capabilities. Within the Future Combat System, the MULE and ARV share the same autonomous navigation system, toward which much of the ARL robotics research has been directed.

The Review Team was given a demonstration of the XUV prototype at ARL’s Fort Indiantown Gap Robotics facility in Pennsylvania. This facility provides a realistic testbed that facilitates validation and integration of algorithms for autonomous and semiautonomous vehicles. The XUV testbed allows alternative algorithms to be compared on a common platform and vulnerabilities to be investigated through realistic experiments. The Review Team appreciated the unusual complexity of the test course, which consists of a mix of road and wooded terrain. It was obvious that the development of the XUV prototype has benefited from a combination of careful engineering, teamwork, and system integration.

The Review Team was positively impressed by the navigation capabilities demonstrated by the XUV on the difficult test terrain. Particularly notable were the maturity of the technology for an experimental program, the extent to which the XUV has been tested to date, and the excellent capability to recover autonomously from close encounters and software restarts. However, a more accurate perception of ditches and extended laser sensing capabilities will be required to operate reliably at higher speeds and on varying terrain. Some architectural issues regarding the coupling of perception to motor skill and the coupling of perception to low-level mobility are areas of improvement worthy of future investigation.

It was clear from the review that the progress of the XUV program benefited from close interaction between researchers from the Sensors and Electron Devices Directorate (SEDD), WMRD, the Human Research and Engineering Directorate (HRED), and the Computational and Information Sciences Directorate (CISD). Furthermore, the review revealed several new opportunities for collaboration across ARL, CTA, and Army Research Office (ARO) programs. Therefore, ARL seems well poised for development of the next generation of robot vehicle systems with more advanced sensing capabilities, higher navigation speeds, and appropriate levels and forms of effective, efficient human intervention in support of mission requirements.

Opportunities and Challenges

It was widely recognized by the Review Team and by ARL robotics researchers that the three principal challenges to practical and reliable autonomous vehicle deployment in the field are robustness/reliability, navigation speed, and perception of the environment. The Review Team and the Board understand that ARL's shorter-term objective of demonstrating the feasibility of autonomous robot vehicles precluded investigating a large number of design architectures. However, scientific progress usually requires an exploration of alternative, potentially superior architectures. The robotics activities at ARL would benefit from more attention to the science, especially in the areas of perception and intelligent control. For example, sticking to a single architecture (e.g. D* planning and Four-Dimensional Real-time Control System [4D/RCS] intelligent control) is acceptable for an early-prototype XUV, but other architectures should be considered for the next-generation robot vehicle.

Human-robot interfaces (HRIs) is another area in which a more systematic, top-down design process would be of value. For example, while the demonstrated Operator Control Unit (OCU) is intuitively appealing, additional work remains to be done in user validation, validation of the heuristic rules used for interaction, and more sophisticated path planning. Furthermore, while a comprehensive Technology Readiness Level 6 experiment and human-factors evaluation of human workload were performed, future generations of the OCU could benefit from the inclusion of more explicit test hypotheses, more rigor in metric and attribute definition, better parameter selection, and specific exit criteria.

The CTA supports research in robust local and global planning, maneuvering in dynamic environments, tactical behaviors, and collaborative operations. These methods did not seem sufficiently mature to be integrated into the demonstration XUV prototype, however. The Review Team and the Board have some concern that the decoupling of the research in perception and intelligent control functions and the modularization of these functions in the architecture have created some difficulties in achieving robust navigation performance. This problem could be a major obstacle to the development of an operational system having sufficient performance and reliability for deployment in the battlefield.

The obstacle described above can possibly be overcome by adopting a more basic, top-down design approach, including the development of a clearer understanding of current capabilities of technology, principal challenges to the technology, and viable strategies for meeting these challenges. This type of strategic thinking would be of benefit to research planning and would also help identify potentially useful areas for collaboration. Such open-ended thought experiments would be an excellent way to involve the problem-solving skills of academic CTA partners. Closer coupling of the CTA would likely have significant impact, perhaps even exceeding previous successes in this area (e.g., the transition of laser detection and ranging [LADAR] sensing technology to the XUV prototype).

Longer-term benefits may accrue by exploiting synergies between ARL robotics activities and the ARO 6.1 Intelligent Control program. In particular, the Review Team considered groundbreaking and relevant the adaptive distributed-control research supported by the ARO and presented by the respective

ARO program manager. The Board encourages continued and expanded interactions between ARL and ARO in areas relevant to robotics.

CONTRIBUTIONS TO ARMY NEEDS AND THE BROADER COMMUNITY

Contributions to Army Needs

ARL's core robotics activities are highly relevant, indeed critical, to the Army mission. ARL robotics researchers are actively deploying new perception, control, robot supervision, and mission packages on unmanned ground vehicle platforms with the potential for transition to the Future Combat System and other Department of Defense programs. The progress of the MULE and XUV prototypes has been impressive. For example, the XUV received a positive report from the Tank-Automotive Research, Development and Engineering Center at Demo III in 2003.

Contributions to the Broader Community

The XUV development program has strong linkages to the academic community through the robotics and perception projects within the CTA. The XUV platform is a state-of-the-art testbed that has been used to test and validate algorithms developed by CTA partners. This allows academic researchers to evaluate performance and failure modes of their algorithms in a realistic operational environment.

RELEVANCE OF CROSSCUTTING ISSUES

The robotics effort at ARL should involve more interaction between the HRED, SEDD, ARO's 6.1 Intelligent Control program, and the Advanced Decision Architectures and the Robotics CTAs in order to improve understanding of and the interaction between physics models, feature representations, control algorithms, and human factors. In particular, HRED should be more involved in assessment during the early stages of the design cycle. Such HRED involvement would be to ensure that the capabilities and limitations of the soldier are taken into account and to ensure that robotics developments are undertaken with cognizance of the systems requirements that encompass both robots and soldiers. It would be most effective for HRED to coordinate human-factors studies with the customer (e.g., at BattleLab at Fort Leonard Wood, Missouri) once a prototype is ready for customer evaluation.

Appendixes

Appendix A

Army Research Laboratory Organization Chart, Resources, and Directorate Staffing Profile

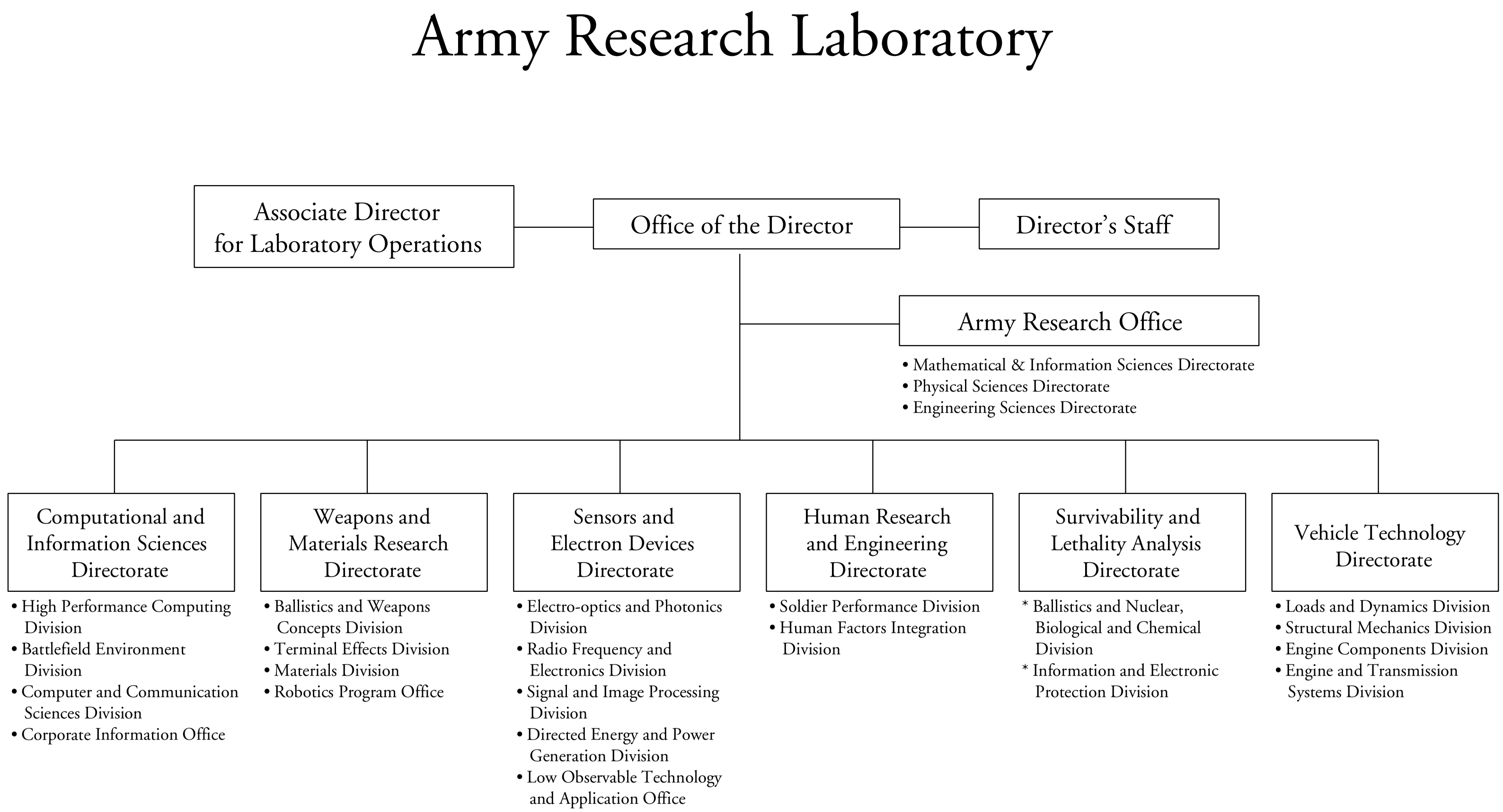

FIGURE A.1 Army Research Laboratory organization chart as of August 19, 2004.

TABLE A.1 Resources: Army Research Laboratory Funding by Technical Unit, FY03 and FY04 (millions of dollars)

		Technical Unit								
Type of Funding	FY	ARO	CISD	HRED	SEDD	SLAD	VTD	WMRD	Mgmt Support	Total
6.1	FY03	89.6	15.3	2.6	9.7	0.0	4.0	22.3	0.0	143.5
	FY04	181.4	13.2	2.6	20.5	0.0	3.5	20.0	0.0	241.2
6.1[a]	FY03	0.0	7.5	5.7	11.4	0.0	0.0	0.0	0.0	24.6
	FY04	0.0	7.9	6.0	11.9	0.0	0.0	2.4	0.0	28.2
6.2	FY03	0.0	17.9	19.6	51.4	6.8	4.5	83.1	2.1	185.4
	FY04	0.0	16.8	23.7	62.3	6.5	4.5	82.7	0.0	196.5
6.2[b]	FY03	0.0	0.0	0.0	0.0	0.0	0.0	5.4	0.0	5.4
	FY04	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	7.5
6.3/6.4/6.7	FY03	0.0	6.9	0.2	0.0	0.1	0.0	12.8	0.0	20.0
	FY04	0.0	0.0	0.0	7.2	1.0	0.0	14.5	0.0	22.7
6.6[c]	FY03	21.4	0.0	0.0	0.0	34.3	0.0	0.0	17.6	73.3
	FY04	30.9	0.0	0.0	0.0	40.2	0.0	0.0	30.0	101.1
6.6[d]	FY03	0.0	2.7	3.1	0.0	0.0	0.0	0.2	7.1	13.1
	FY04	0.0	0.1	3.0	0.0	0.0	0.0	0.0	4.7	7.8
Customer	FY03	2.8	28.6	7.9	22.7	15.4	1.0	45.5	2.0	125.9
Reimbursement[e]	FY04	3.3	12.9	7.7	36.4	17.7	1.4	44.5	0.5	124.4
Customer Direct	FY03	50.1	6.8	16.7	15.9	3.5	0.0	4.8	0.0	97.8
Citation[f]	FY04	48.2	5.3	0.3	17.8	10.3	0.0	5.7	0.0	87.6
OMA[g]	FY03	0.5	7.4	0.0	0.0	0.0	0.0	0.5	38.2	46.6
	FY04	0.0	0.6	0.0	0.0	0.0	0.0	1.9	4.8	7.3
OSD[h]	FY03	99.4	1.8	0.0	2.4	0.0	0.0	0.4	0.0	104.0
	FY04	21.2	18.8	0.0	0.0	0.0	0.0	0.0	0.0	40.0
DARPA[i]	FY03	89.7	1.5	0.1	44.9	0.2	0.0	2.9	0.4	139.7
	FY04	77.5	1.1	0.0	44.4	0.1	0.0	2.8	0.0	125.9
MSRC/HPC[j]	FY03	0.0	64.3	0.0	0.0	0.0	0.0	0.0	0.0	64.3
	FY04	0.0	57.7	0.0	0.0	0.0	0.0	0.0	0.0	57.7
Total	FY03	353.5	160.7	55.9	158.4	60.3	9.5	177.9	67.4	1043.6
	FY04	362.5	134.4	43.3	200.5	75.8	9.4	182.0	40.0	1047.9

[a]6.1 Collaborative Technology Alliances (formerly Federated Laboratory).
[b]6.2 Collaborative Technology Alliances.
[c]6.6 Technology Analysis (SLAD, Small Business Innovation Research/Small Business Technology Transfer, Field Assistance in Science and Technology, Board on Army Science and Technology, Soldier Centered Analysis, and PE 65803 [Technical Information Activities]).
[d]6.6 Management Support (Base Support).
[e]Reimbursement from customers.
[f]Direct citation of funds from customers.
[g]Operation and Maintenance, Army.
[h]Office of the Secretary of Defense.
[i]Defense Advanced Research Projects Agency.
[j]Major Shared Resource Center and High-Performance Computing (includes Mission, OSD, and Customer Reimbursable).

TABLE A.2 Army Research Laboratory Staffing Profile (as of December 31, 2004)

Staffing Information	ARL-Wide	Dir Ofc	CISD	HRED	SEDD	SLAD	VTD	WMRD
Total Civilian Staff	1917	38	313	217	376	294	84	403
Number [%] S&Es	1311 [68%]	23 [61%]	200 [64%]	162 [75%]	297 [79%]	236 [80%]	61 [73%]	282 [70%]
Number [%] Technicians	205 [11%]	0	16 [5%]	11 [5%]	46 [12%]	32 [11%]	11 [13%]	89 [22%]
Number [%] Admin. Personnel	401 [21%]	15 [39%]	97 [31%]	44 [20%]	33 [9%]	26 [9%]	12 [14%]	32 [8%]
Other Personnel								
Number Military Personnel	49	2	6	3	4	15	5	5
Number Postdoctoral Researchers	7	0	1	1	4	0	1	0
Number Guest Researchers	16	0	2	3	11	0	0	0
Number On-Site Contractors	632	11	286	1	61	80	0	133
Of S&Es: Education								
Number [%] with B.S. or B.A.	412 [31%]	5 [22%]	80 [40%]	64 [40%]	85 [29%]	136 [58%]	23 [38%]	101 [36%]
Number [%] with M.S. or M.A.	458 [35%]	13 [56%]	69 [35%]	51 [31%]	97 [32%]	78 [33%]	16 [26%]	62 [22%]
Number [%] with Ph.D.	429 [34%]	5 [22%]	51 [25%]	47 [29%]	115 [39%]	22 [9%]	22 [36%]	119 [42%]
Of S&Es: Ages								
Number [%] under 25	60 [5%]	0	11 [6%]	14 [9%]	8 [3%]	19 [8%]	0	8 [3%]
Number [%] 25-35	155 [12%]	0	19 [10%]	25 [15%]	33 [11%]	18 [8%]	7 [12%]	48 [17%]
Number [%] 35-45	428 [33%]	2 [9%]	63 [31%]	36 [22%]	112 [38%]	82 [35%]	28 [46%]	97 [34%]
Number [%] 45-55	370 [28%]	9 [39%]	65 [32%]	53 [33%]	81 [27%]	65 [27%]	14 [23%]	74 [26%]
Number [%] 55-65	250 [19%]	8 [35%]	36 [18%]	28 [17%]	52 [17%]	42 [18%]	10 [16%]	50 [18%]
Number [%] over 65	48 [3%]	4 [17%]	6 [3%]	6 [4%]	11 [4%]	10 [4%]	2 [3%]	5 [2%]

NOTE:
S&Es—scientists and engineers
Dir Ofc—Director's Office
CISD—Computational and Information Sciences Directorate
HRED—Human Research and Engineering Directorate
SEDD—Sensors and Electron Devices Directorate
SLAD—Survivability and Lethality Analysis Directorate
VTD—Vehicle Technology Directorate
WMRD—Weapons and Materials Research Directorate
SOURCE: Army Research Laboratory.

Appendix B

Membership of the Army Research Laboratory Technical Assessment Board and Its Panels

Army Research Laboratory Technical Assessment Board

Robert W. Brodersen, *Chair*
George E. Dieter
Clive L. Dym
David R. Ferguson
Douglas H. Harris
Mary Jane Irwin
Dwight C. Streit
Dennis W. Thomson

Air and Ground Vehicle Technology Panel
(reviews VTD)

Clive L. Dym, *Chair**
Roy Battles
Julie Chen
Charbel H. Farhat
Jacob Fish
Awatef Hamed
S. Michael Hudson
Sia Nemat-Nasser
Francis W. Zok

Armor and Armaments Panel
(reviews WMRD)

George E. Dieter, *Chair**
Charles E. Anderson, Jr.
Melvin R. Baer
Kim K. Baldridge
Phillip W. Barth
Thomas B. Brill
Rodney J. Clifton
Phillip Colella
Larry G. Hill
James E. McGrath
Lynne E. Parker
Thomas A. Saponas
Rosemary L. Smith
Kenneth S. Vecchio
John D. Venables

Digitization and Communications Science Panel
(reviews CISD)

Mary Jane Irwin, *Chair**
Nancy M. Amato
Ronald C. Arkin
Donald M. Chiarulli
Phillip Colella
Jack Dongarra
Joel S. Engel
Brant Foote
Joseph Halpern
Bruce B. Hicks
Frank A. Horrigan
Daniel E. Koditschek
Peter Kogge
Vijay Kumar
Mitchell P. Marcus
Richard T. McNider
Jimmy K. Omura
Charles F. Reinholtz
Dennis W. Thomson*
David Waltz

Nanotechnology Review Team

Peter Kogge, *Chair*
Kim K. Baldridge
Phillip W. Barth
Robert W. Brodersen *
James E. McGrath
Thomas A. Saponas
Rosemary L. Smith
Dwight C. Streit*

Robotics Review Team

Alfred O. Hero, *Chair*
Nancy Amato
Ronald Arkin
Robert T. Hennessy
Frank A. Horrigan
Daniel Koditschek
Vijay Kumar
Charles Reinholtz
David Waltz

Sensors and Electron Devices Panel
(reviews SEDD)

Dwight C. Streit, *Chair**
Henry E. Bass
Robert W. Brodersen*
Elton J. Cairns
L. Richard Carley
Arthur Guenther
Alfred O. Hero
Narain G. Hingorani
Keith H. Jackson
Linda P.B. Katehi
Timothy N. Krabach
Karen W. Markus
David C. Munson, Jr.
P. Paul Ruden
John F. Schultz
Fritz Steudel

Soldier Systems Panel
(reviews HRED)

Douglas H. Harris, *Chair**
Donald B. Chaffin
Dennis G. Faust
Robert T. Hennessy
Robert A. Henning
Bonnie Elizabeth John
John D. Lee
Eric R. Muth
Frank E. Ritter

Survivability and Lethality Analysis Panel
(reviews SLAD)

David R. Ferguson, *Chair**
Romesh C. Batra
John D. Christie
MarjorieAnn EricksonKirk
Melvin F. Kanninen
Richard Lloyd
Teresa F. Lunt
John McHugh
Max D. Morris
John Reese
John F. Schultz
Jack L. Walker
Donald C. Wunsch

*ARLTAB Member.
NOTE: Members whose term expired prior to 2004 are included in the Biographical Sketches in this appendix.

FIGURE B.1 Army Research Laboratory Technical Assessment Board and Panels, 2004.

BIOGRAPHICAL SKETCHES

Army Research Laboratory Technical Assessment Board

ROBERT W. BRODERSEN, *Chair*, is a member of the National Academy of Engineering (NAE), the John Whinnery Chair Professor in the Electrical Engineering and Computer Science Department at the University of California at Berkeley, and co-scientific director of the Berkeley Wireless Research Center. His expertise is in solid-state circuitry and microelectronics, and his current research is in new applications of integrated circuits focused in the areas of low-power design and wireless communications and the computer-aided design (CAD) tools necessary to support these activities. Professor Brodersen is a fellow of the Institute of Electrical and Electronics Engineers (IEEE) and has received numerous prestigious awards throughout his career. He received his Ph.D. in electrical engineering from the Massachusetts Institute of Technology (MIT). He is a former member of the Army Research Laboratory Technical Assessment Board (ARLTAB) Sensors and Electron Devices Panel, having served with distinction from 1996 through 2000.

GEORGE E. DIETER is the Glenn L. Martin Institute Professor of Engineering at the University of Maryland, formerly serving as dean of engineering at the university until 1994. Before coming to the University of Maryland in 1977, he was a professor of engineering and director of the Processing Research Institute at Carnegie Mellon University. Earlier in his career, Dr. Dieter worked for the DuPont Engineering Research Laboratory before serving as head of the Metallurgical Engineering Department and later as dean of engineering at Drexel University. He received his D.Sc. degree from Carnegie Mellon University and is a fellow of ASM International (the society for materials engineers and scientists); the Minerals, Metals, and Materials Society (TMS); the American Association for the Advancement of Science (AAAS); and the American Society for Engineering Education (ASEE). He has received the education award from ASM, TMS, and the Society for Manufacturing Engineers (SME), as well as the Lamme Medal, the highest award of the ASEE. In addition, he has been chair of the Engineering Deans Council and president of the ASEE. Dr. Dieter is a member of the NAE and the author of two widely used books, *Mechanical Metallurgy* and *Engineering Design: A Materials and Processing Approach*.

CLIVE L. DYM is the Fletcher Jones Professor of Engineering Design and director of the Center for Design Education at Harvey Mudd College. His primary interests are in engineering design and structural mechanics. After receiving his Ph.D. from Stanford University, Dr. Dym held appointments at the University of Massachusetts, Amherst; Bolt, Beranek and Newman; Carnegie Mellon University; the Institute for Defense Analyses; and the University at Buffalo. He was also head of the Civil Engineering Department at the University of Massachusetts (1977-1985) and chair of the Department of Engineering at Harvey Mudd (1999-2002). Dr. Dym has held visiting appointments at the TECHNION-Israel Institute of Technology; University of Southampton Institute of Sound and Vibration Research; Stanford University; Xerox PARC; Carnegie Mellon University; Northwestern University; and the University of Southern California. He has authored or coauthored 10 books and more than 100 archival publications and technical reports. Dr. Dym was founding editor of the journal *Artificial Intelligence for Engineering Design, Analysis, and Manufacturing* and is currently associate editor of the American Society of Mechanical Engineers (ASME) *Journal of Mechanical Design*. Dr. Dym's many awards include the Walter L. Huber Research Prize (American Society of Civil Engineers [ASCE], 1980), the Fred Merryfield Design Award (ASEE, 2002), and the Joel and Ruth Spira Outstanding Design Educator Award (ASME, 2004).

DAVID R. FERGUSON was Boeing Phantom Works' senior geometry technical fellow before his recent retirement. In that position, he had lead responsibility for geometry research and development at Boeing, where his work involved the application of mathematics to a wide variety of real-world engineering problems. He worked extensively on issues related to computer-aided geometric design and in the specific area of developing mathematical algorithms for curve and surface generation, and he has written and spoken widely on the issue of shape control for geometric objects. Before joining Boeing, Dr. Ferguson worked with the Aerospace Corporation and was a member of the faculty at the University of Wisconsin and the University of Southern California. Dr. Ferguson is a member of the Society for Industrial and Applied Mathematics (SIAM) and an editor for two professional journals.

DOUGLAS H. HARRIS is chairman and principal scientist of Anacapa Sciences, a company that he formed in 1969 to improve human performance in complex systems and organizations. His principal contributions have been in the areas of inspection, investigation, intelligence, and maintenance performance. Dr. Harris is a past president of the Human Factors and Ergonomics Society and a past chair of the National Research Council (NRC) Committee on Human Factors. He was an author of the first volume of the Wiley Series in Human Factors (*Human Factors and Quality Assurance*) and was chair of an NRC panel that produced the book *Organizational Linkages: Understanding the Productivity Paradox*. As an officer in the U.S. Navy, he completed underwater demolition training and served as the operations and training officer of an underwater demolition team.

MARY JANE IRWIN is the A. Robert Noll Chair in Engineering in the Department of Computer Science and Engineering at Pennsylvania State University. Her expertise is in computer architecture, embedded and mobile computing systems design, low-power design, and electronic design automation. Dr. Irwin was named fellow of the Institute of Electrical and Electronics Engineers in 1995 and fellow of the Association for Computing Machinery (ACM) in 1996, and she was elected to the National Academy of Engineering in 2003. Dr. Irwin is currently serving as the editor in chief of the ACM's *Transactions on Design Automation of Electronic Systems*. In the past, she has served as an elected member of the Computing Research Association's board of directors, IEEE Computer Society's board of governors, and ACM's council, and as vice president of the ACM. She received her Ph.D. in computer science from the University of Illinois at Urbana-Champaign.

RICHARD S. MULLER (Board member in 2003) is a member of the NAE, director of the Berkeley Sensor and Actuator Center, and professor in the Department of Electrical Engineering and Computer Sciences at the University of California at Berkeley. His expertise includes microelectromechanical systems (MEMS) and integrated electronic sensors. Dr. Muller is coauthor of the popular textbook *Device Electronics for Integrated Circuits* and author or coauthor of more than 200 technical papers and the inventor of 16 patents. In 1986, he joined with Professor Richard White to found the Berkeley Sensor and Actuator Center, a National Science Foundation (NSF)/industry/university research center. Dr. Muller has received many prestigious awards throughout his career. He is a life fellow of the IEEE, an IEEE Distinguished Lecturer, editor in chief of the IEEE/ASME *Journal of Microelectromechanical Systems*, a trustee of the Stevens Institute of Technology, and a former member of the National Research Council's National Materials Advisory Board. He presently serves as chair for Microsystem Technologies on the (German) Helmholtz Association for the review of German Federal Research Laboratories.

JOHN C. SOMMERER (Board member in 2003) is chief technology officer of the Johns Hopkins University Applied Physics Laboratory (JHU/APL), and he chairs APL's Science and Technology

Council. He manages APL's overall internal research and development (R&D) program, its participation in the educational programs of JHU's Whiting School of Engineering, and its Office of Technology Transfer, and he is the line supervisor of the Research and Technology Development Center. In addition, he is an adjunct faculty member in applied physics, applied mathematics, and technical management. Dr. Sommerer has made internationally recognized theoretical and experimental contributions to the fields of nonlinear dynamics and complex systems. He has served on several technical advisory bodies for the U.S. government and has received numerous prestigious awards. Dr. Sommerer is a member of the Security Affairs Support Association, the American Physical Society (APS) and its Division of Fluid Mechanics, and SIAM and its Activity Group on Dynamical Systems. He is a director of the James Rouse Entrepreneurial Fund. He holds a Ph.D. in physics from the University of Maryland.

DWIGHT C. STREIT is an NAE member and the vice president of Foundation Technologies at Northrop Grumman Space Technology. He has overall responsibility for development of the basic engineering, science, and technology required for space and communications systems. He has extensive experience in semiconductor devices and Microwave and Millimeter Integrated Circuits (MMICs) for applications up to 220 GHz, as well as in infrared and radiometer sensors. He has led development efforts for 10 to 40 Gbps optical communications systems and has experience in the development and production of optoelectronic devices and circuits. He also has previous experience in frequency modulated continuous wave (FMCW) and phased-array product development for X-band to W-band radar applications. He received his Ph.D. in electrical engineering from the University of California at Los Angeles.

DENNIS W. THOMSON is a professor and former department head in the Department of Meteorology at the Pennsylvania State University. His expertise is in atmospheric physics and remote atmospheric sensing, and his major research interests include atmospheric electromagnetic and acoustic propagation phenomena, remote sensing of winds and turbulence, atmospheric sounds and noise propagation, boundary layer structure and processes, micrometeorology, and nonlinear dynamical systems. Dr. Thomson has received a number of prestigious awards; he is a fellow of the American Meteorological Society (AMS) and a former Intergovernmental Personnel Act (IPA) fellow to the Office of Naval Research. Other off-campus assignments for Dr. Thomson, on Penn State's faculty for more than 32 years, include those with the Risoe National Laboratory, Denmark, and the Naval Postgraduate School. His national science community responsibilities have included a term as trustee of the University Corporation for Atmospheric Research, membership on a number of Department of Defense (DOD) oversight and advisory committees, and extended service, both to the Argonne National Laboratory and continuing at the Lawrence Livermore National Laboratory. He is a multidegree graduate in physics and meteorology (Ph.D.) of the University of Wisconsin.

Staff

JAMES P. McGEE is director of the Army Research Laboratory Technical Assessment Board (ARLTAB) in the Division on Engineering and Physical Sciences at the National Research Council. Since 1994, he has been a senior staff officer at the NRC, directing projects in the areas of systems engineering and applied psychology, including the Panel on Soldier Systems for ARLTAB, the Committee on National Statistics' Panel on Operational Testing and Evaluation of the Stryker Vehicle and its Committee on Assessing the National Science Foundation's Scientists and Engineers Statistical Data System, the Committee on the Health and Safety Needs of Older Workers, and the Steering Committee on Differential Susceptibility of Older Persons to Environmental Hazards. He has also served as staff officer for NRC projects on Air Traffic Control Automation, Musculoskeletal Disorders and the Workplace, and the Changing Nature of Work. Prior to joining the NRC, Dr. McGee held technical and management positions in systems engineering and applied psychology at IBM, General Electric, RCA, General Dynamics, and United Technologies corporations. He received his B.A. from Princeton University and his Ph.D. from Fordham University, both in psychology, and for several years instructed postsecondary courses in applied psychology and in organizational management.

CY L. BUTNER is a senior program officer with the Army Research Laboratory Technical Assessment Board. Shortly after joining the NRC in 1997, he moved from the Aeronautics and Space Engineering Board (ASEB) to his current appointment. Before joining the NRC, Mr. Butner served as an independent consultant to the ASEB for 2 years, during which time he supported an ongoing peer review process for Air Force Office of Scientific Research proposals, as well as several reports on topics related to space and aeronautics programs. From 1985 until 1994, Mr. Butner worked with two aerospace consulting firms, where he supported space and aeronautics technology development programs at National Aeronautics and Space Administration (NASA) Headquarters. Before that, he worked for RCA as a satellite solar array engineer, for NASA at the Goddard Space Flight Center as a science cooperative education program student and a materials engineer, and for the New Mexico Environmental Improvement Agency as a statistician. Mr. Butner has B.S. and M.S. degrees in physics from the American University and a B.S. degree in mathematics from the University of New Mexico.

RADHIKA S. CHARI is the administrative coordinator for the Army Research Laboratory Technical Assessment Board and the Board on Assessment of National Institute of Standards and Technology Programs of the National Research Council. She has been with the National Academies since 1996. Prior to joining these boards, she was a senior project assistant for the Board on Earth Sciences and Resources in the Division on Earth and Life Sciences. Ms. Chari received her B.A. degree in philosophy from Fordham University.

Air and Ground Vehicle Technology Panel

CLIVE L. DYM, *Chair* (see Board sketches, above)

ROY BATTLES is senior vice president of research and engineering at Bell Helicopter Textron. Mr. Battles has more than 30 years of experience in several areas of rotorcraft engineering. His responsibilities have included contracted and company research on drive system programs, drive system design and analysis, drive system bench testing, rotor system design and analysis, hydraulic design, controls design, wheeled landing gear design, and wiring design. Mr. Battles has participated in several rotorcraft developments and qualifications and has authored and presented technical papers on helicopter drive systems. He was awarded the Distinguished Engineer Award at Texas Tech University in 2002.

JULIE CHEN is a professor of mechanical engineering and codirector of the Advanced Composite Materials and Textile Research Laboratory at the University of Massachusetts at Lowell. Dr. Chen is currently on temporary assignment as program director for Nanomanufacturing at the National Science Foundation. Her expertise covers the areas of mechanical behavior and deformation of fiber structures, fiber assemblies, and composite materials, with an emphasis on experimental investigation and analytical modeling of processing, energy absorption, fatigue, and failure behavior of composites. She received her Ph.D. in mechanical engineering from MIT.

MICHAEL G. DUNN (panel member in 2003) has more than 35 years of industry experience at the Lockheed Missiles and Space Company and Calspan Corporation (formerly the Cornell Aerospace Laboratory). In 1995 he moved to the Ohio State University, where he is director of the Gas Turbine Laboratory. Dr. Dunn has extensive R&D experience in the areas of hypersonic flows and the fundamentals of turbomachinery flows. He has participated in research programs with all of the U.S. aircraft engine manufacturers, as well as those of NASA, Wright-Patterson Air Force Base, and the Defense Nuclear Agency. Dr. Dunn pioneered the use of short-duration experimental techniques to obtain fundamental measurements at design-corrected conditions for a host of full-stage rotating turbines. He is the author or coauthor of more than 150 reports and archival publications.

CHARBEL H. FARHAT is a professor in the Department of Mechanical Engineering and the Institute for Computational and Mathematical Engineering at Stanford University. Previously, he was the chair of the Department of Aerospace Engineering Sciences and director of the Center for Aerospace Structures at the University of Colorado at Boulder. He is a leader in the area of computational mechanics, and his research interests include aeroelasticity, acoustics, coupled field problems, finite element methods and software, numerical analysis, substructuring and domain decomposition methods, mesh partitioning, parallel processing, scientific visualization, engineering design, and engineering software systems. Dr. Farhat has received numerous honors and awards. He is a consultant to major corporations; Sandia National Laboratories; the European Space Agency; SAMTECH, S.A., in Belgium; the Department of the Air Force; and the National Science Foundation. He is a fellow of the International and the U.S. Association for Computational Mechanics (IACM and USACM), the American Society for Mechanical Engineers, and the American Institute of Aeronautics and Astronautics (AIAA), and the World Innovation Foundation. Dr. Farhat sits on a number of editorial boards and has served on many prestigious advisory committees. He received his Ph.D. in civil engineering from the University of California at Berkeley.

JACOB FISH is a professor in the Departments of Civil Engineering, Mechanical and Aerospace Engineering, and Information Technology at Rensselaer Polytechnic Institute. Dr. Fish has expertise in advanced materials, fracture, modeling, high-performance computing, and structural integrity. He has worked on various aspects of structural integrity modeling and analysis and has developed multiscale computational techniques for advanced materials and structures. He is editor in chief of the *Journal for Multiscale Computational Engineering* and currently serves as the president of the U.S. Association for Computational Mechanics. Dr. Fish is a fellow of both the USACM and the IACM. He is a consultant to the NY Department of Law, General Electric Corporate Research and Development, Lockheed Missiles and Space Company, and the ANSYS, SDRC, and EMRC software houses. He received his Ph.D. in theoretical and applied mechanics from Northwestern University.

AWATEF HAMED is department head and the Bradley Jones Professor in the Aerospace Engineering and Engineering Mechanics Department of the University of Cincinnati. Dr. Hamed has more than 30 years of research experience in gas turbine erosion, two-phase flow, aeroacoustics, and propulsion systems integration. She has written more than 300 technical publications, is chair of the ASME Fluids Applications Systems Technical Committee, and is editor of the *International Journal of Computational Fluid Dynamics*. She is a fellow of both the AIAA and the ASME, as well as being a member of the ASEE. Dr. Hamed has received a number of prestigious awards throughout her career. She received her Ph.D. in engineering from the University of Cincinnati.

S. MICHAEL HUDSON retired in 2002 from the position of vice chairman of Rolls-Royce North America. After Allison Engine Company was acquired by Rolls-Royce, Mr. Hudson served as president, chief executive officer, chief operating officer, and as a member of the board of directors of Allison Engine Company. Previously, during his tenure at Allison, he served as executive vice president for engineering, chief engineer for advanced technology engines, chief engineer for small production engines, supervisor of the design for Model 250 engines, and chief of preliminary design and chief project engineer in vehicular gas turbines. Mr. Hudson is a member of the NRC's Aeronautics and Space Engineering Board and has served as a member of several of the ASEB's committees.

SIA NEMAT-NASSER is a professor of mechanical and aerospace engineering and director of the Center of Excellence for Advanced Materials at the University of California at San Diego. His current research includes micromechanical and constitutive modeling of nonlinear response and failure modes, analytic and computational mechanics, static and dynamic experimental development of lightweight structures made of shape-memory alloys, and development of a self-healing composite material. Previously, from 1970 to 1985, he was professor of applied mechanics and applied mathematics at Northwestern University. Dr. Nemat-Nasser is a member of the NAE; a fellow of the ASME; a fellow and past president of the Society of Engineering Science (SES); a founding member, fellow, past secretary, and past president of the American Academy of Mechanics (AAM); and a foreign fellow of the Danish Center for Applied Mathematics and Mechanics. He is editor in chief of the international journal *Mechanics of Materials*, edited the book series *Mechanics Today* and the book series *Mechanics of Elastic and Inelastic Solids*, and has authored, coauthored, or edited more than 19 books and proceedings. He received his Ph.D. in structural mechanics from the University of California, Berkeley.

FRANCIS W. ZOK is a professor in the Materials Department at the University of California at Santa Barbara and director of the university's High Performance Composites Center. Dr. Zok has expertise in the mechanical and thermal behavior of multiphase structural materials, especially nonlinear damage phenomena, and the development of engineering design and life prediction methodologies based on micromechanical descriptions of the pertinent phenomena. His research encompasses a broad range of materials systems, including fiber-reinforced metals, ceramics, and polymers; particulate-, whisker-, and microballoon-reinforced metals; hybrid ceramic/composite laminates; ceramic fibrous monoliths; and systems with novel reinforcement topologies designed for ultrahigh energy absorption. He has been associate editor of the *Journal of the American Ceramic Society* since 1993. He is the author of more than 100 scientific papers and 5 book chapters. He received his Ph.D. from McMaster University.

Armor and Armaments Panel

GEORGE E. DIETER, *Chair* (see Board sketches, above)

CHARLES E. ANDERSON, JR., is director of the Engineering Dynamics Department of the Mechanical and Materials Engineering Division of the Southwest Research Institute. He is an expert in penetration mechanics and hypervelocity impact. In particular, he has worked to modify and improve Eulerian and Lagrangian hydrodynamic computer codes for use in material response studies, penetration mechanics and hypervelocity impact studies, and warhead fragmentation design and analyses. He has authored numerous government reports and, because of his expertise in penetration and computational mechanics, has served on various government advisory committees. Dr. Anderson is a founding board member and the first president of the Hypervelocity Impact Society, a senior institute fellow of the

Institute for Advanced Technology, a member of the editorial advisory board of the *International Journal of Impact Engineering*, and recipient of the Distinguished Scientist Award (2000). Dr. Anderson received his Ph.D. in physics from Rensselaer Polytechnic Institute.

MELVIN R. BAER is a senior scientist in engineering sciences at the Sandia National Laboratories. Over the past 25 years, he has published fundamental and basic research in the field of energetic materials involving the initiation, deflagration, and detonation processes in propellants, explosives, intermetallics, and pyrotechnics. He has served as a consultant in energetic materials for several government agencies and has participated in numerous explosives review and investigation programs, such as the Advanced Energetics Integrated Process Team (IPT), the U.S. Navy reinvestigation of the USS *Iowa* incident, and the National Transportation Safety Board investigation of the 1996 TWA 800 accident. Dr. Baer received his Ph.D. in mechanical engineering from Colorado State University.

KIM K. BALDRIDGE is director of Computational Applications and professor of theoretical chemistry at the University of Zurich, Switzerland. She additionally holds a distinguished scientist position at the San Diego Supercomputer Center and an adjunct professorship in the Department of Chemistry at the University of California at San Diego. Her expertise covers a wide area of computational chemistry, including the following: direct application of quantum chemical software; development of new quantum chemical algorithms; and development of visualization, middleware, database, and analysis tools for the adaptation of computational chemistry and biochemistry applications to grid environments. Dr. Baldridge is a fellow of the American Physical Society and of the American Association for the Advancement of Science. She is coauthor of a major computational chemistry software package used worldwide and has a publication list of 100 research articles.

PHILLIP W. BARTH is credited with coining the term “surface micromachining” as applied to MEMS. At Agilent Technologies (formerly known as Hewlett-Packard), he has contributed innovative engineering content to areas of work including synthetic nanopore manufacturing methods, microfluidic systems for genomics array manufacturing, microfluidics for high-throughput screening systems, optical switching systems for telecommunications, liquid handling for inkjet printing, microscale valves, and microscale flow detectors. In prior positions, as vice president/chief scientist at NovaSensor and as a senior research associate in Stanford University’s Center for Integrated Systems, he codeveloped airbag accelerometers, fuel injectors, pressure sensors, and thermometer arrays. He is inventor or coinventor of 34 issued U.S. patents and author or coauthor of 12 refereed journal articles and 36 other publications. He has approximately 10 patents pending.

THOMAS B. BRILL is a professor of chemistry, chemical engineering, and art conservation at the University of Delaware. Dr. Brill is a widely known leader in research related to the chemistry of propellants and explosives. His current research is aimed at gaining fundamental insights into chemical processes at rather extreme conditions, including the study of pyrolysis processes that occur on the surface of burning materials. Dr. Brill also has served as a member of the National Research Council’s Committee on Advanced Energetic Materials and Manufacturing Technologies. He received his Ph.D. in chemistry from the University of Minnesota at Minneapolis.

RODNEY J. CLIFTON is Rush C. Hawkins University Professor at Brown University and an NAE member. His expertise is in dynamic plasticity, dynamic fracture, and phase transformations. His research includes plate impact theory and experiments, dynamic plasticity, dislocation dynamics, dynamic fracture, mechanics of hydraulic fracturing, and numerical methods. In addition to his position at Brown University, Dr. Clifton has held visiting positions at the University of Southampton Institute of Sound and Vibration Research, Stanford University, and the Massachusetts Institute of Technology. He has been a consultant to major firms and national laboratories, including the Brookhaven National Laboratory and Sandia National Laboratories. He is a fellow of the American Academy of Mechanics and the American Society of Mechanical Engineers. His other professional memberships include those in the APS, SIAM, and ASCE. Dr. Clifton received his Ph.D. in civil engineering from Carnegie Mellon University.

PHILLIP COLELLA is a senior mathematician and group leader of the Applied Numerical Algorithms Group in the Computational Research Division at the Lawrence Berkeley National Laboratory. His expertise is in numerical methods for partial differential equations and their application to science and engineering problems. He is a recipient of the IEEE Computer Society's Sidney Fernbach Award (1998) and the SIAM/ACM prize in computational science (2003) and a member of the National Academy of Sciences (NAS) (2004). Dr. Colella is also a current member of the ARLTAB Digitization and Communications Science Panel.

DENNIS E. GRADY (panel member in 2003) is a principal scientist and associate with the Southwest Division of Applied Research Associates. Dr. Grady's expertise includes impact and penetration phenomena; shock waves; equation-of-state, high-pressure, and high-temperature physics; fracture and fragmentation; and dynamic material properties. For more than 30 years (including 22 years at Sandia National Laboratories), he has been involved with the measurement and theoretical description of condensed matter under the influence of shock and high-velocity impact. Dr. Grady has published more than 200 technical papers and reports. He earned a Ph.D. in physics and mathematics from Washington State University.

LARRY G. HILL is a technical staff member at the Los Alamos National Laboratory (LANL), where he conducts theoretical and experimental research on the performance and safety of high explosives. He has been with LANL since 1992. His experience includes the following areas: propagation and failure of curved detonation waves; inert, product, and mixture equations of state; reaction rate modeling; shock initiation; deflagration-to-detonation transition; and crack and flame propagation in explosives and propellants. Dr. Hill received his Ph.D. in aeronautics from the California Institute of Technology.

JAMES E. McGRATH is director of the Materials Research Institute and University Distinguished Professor of Chemistry at Virginia Polytechnic Institute and State University. Dr. McGrath also is a member of the NAE, American Chemical Society (ACS), Society of Plastic Engineers, Society for the Advancement of Material and Process Engineering, Materials Research Society, and AAAS. His expertise is in polymeric materials and their composites, and his research includes novel polymer synthesis, mechanism and kinetics of polymerization reactions, fluorine- and phosphorus-containing polymers, toughening mechanisms in thermosetting systems, poly(amide)s and poly(aramide)s, liquid crystalline polymers, and small-particle generation for powder prepreg applications. Dr. McGrath has served as director of the National Science Foundation's Science and Technology Center on High Performance Polymeric Adhesives and Composites. He received his Ph.D. in polymer science from the University of Akron.

LYNNE E. PARKER is an associate professor in the Department of Computer Science at the University of Tennessee-Knoxville and an adjunct distinguished research and development staff member in the Computer Science and Mathematics Division at the Oak Ridge National Laboratory. She is a leading international researcher in the field of cooperative multirobot systems and has performed research in the areas of mobile robot cooperation, human-robot cooperation, robotic learning, intelligent agent architectures, and robot navigation. For this research, she was awarded the U.S. Presidential Early Career Award for Scientists and Engineers in 2000. Her extensive publications include four edited books on the topic of distributed robotics. Dr. Parker received her Ph.D. in computer science from MIT.

THOMAS A. SAPONAS was, until his retirement in 2003, the senior vice president and chief technology officer (CTO) for Agilent Technologies, the $8 billion spin-off of the Hewlett-Packard Company in 1999. He had been with Hewlett-Packard (HP) and Agilent Technologies for 31 years, starting as a research and development engineer. As CTO, Mr. Saponas was responsible for establishing Agilent's long-term technology strategy and directly supervised its central research laboratory. Previously, he had been vice president and general manager of the Electronic Instruments Group at HP, where he led eight divisions and five operations. Earlier as a general manager, he was also responsible for HP's worldwide R&D, marketing and manufacturing of oscilloscopes, logic analyzers, and microprocessor development systems, as well as having manufacturing responsibility for HP's thin- and thick-film microcircuits. In 1986, Mr. Saponas was selected as a White House Fellow, and he served for 1 year as special assistant to the Secretary of the Navy. Mr. Saponas has a B.S. degree in computer science and electrical engineering and an M.S. degree in electrical engineering from the University of Colorado.

ROSEMARY L. SMITH is a professor of electrical and computer engineering at the University of California at Davis. She is primarily interested in the design, fabrication, assembly, and testing of microfabricated systems for chemical analysis and biomedical measurements. Microfabricated measurement systems have recently become known as "microinstruments." In the course of the design and fabrication of a microsensor or microinstrument, new technologies and processes have to be invented or developed, including wafer-scale assembly, thin-film materials deposition and etching, and micromachining technologies. Professor Smith's current research includes electrochemiluminescence for chemical sensing and analysis, porous silicon-based sensors, vertical assembly through wafer bonding, and wafer-to-wafer interconnect.

KENNETH S. VECCHIO is a professor of materials science and engineering in the Department of Mechanical and Aerospace Engineering at the University of California at San Diego (UCSD). For 10 years he served as the director of the Electron Optics and Microanalysis Facility for the Jacobs School of Engineering at UCSD. Among his professional distinctions, Dr. Vecchio was the recipient of the Year 2000 Marcus Grossman Young Author Award from ASM International. His research focuses on structure/property relations in advanced materials, with emphasis on applications in dynamic loading events for both civilian and defense-related fields. Central to much of this research is the application and incorporation of rate-sensitive-material models into the analysis of industrially relevant problems, such as the solid particle erosion of ductile alloys, foreign object damage, penetrator/armor interactions, and wear problems. Dr. Vecchio also has a strong interest in fundamental investigations of defect generation and storage mechanisms. A recognized leader in his fields of expertise, Dr. Vecchio also serves as a consultant to several companies. He received his Ph.D. in materials science and engineering from Lehigh University and holds several patents in the field of materials development, including one on layered armor materials.

JOHN D. VENABLES received his Ph.D. in physics from the University of Warwick, England, and until his retirement he served as associate director and chief scientist at Martin Marietta Laboratories in Baltimore, Maryland. He has served on numerous study committees of the National Academies and was a member for 6 years of BAST, the Board on Army Science and Technology. He is the coauthor of the entry entitled "Materials Science" in the *Encyclopedia Britannica* and is currently a consultant for the Defense Advanced Research Projects Agency's (DARPA's) Defense Sciences Office (DSO) through Strategic Analysis, Inc.

SHELDON WIEDERHORN (panel member in 2003) is a senior NIST fellow in the Materials Science and Engineering Laboratory of the National Institute of Standards and Technology. With 41 years of experience at NIST (formerly the National Bureau of Standards) and 3 years at E.I. du Pont de Nemours and Company before that, he is a recognized leader in the field of ceramics. He has broad expertise, with a particular focus on the mechanical properties of ceramics. Dr. Wiederhorn is a member of the NAE and a fellow of the American Ceramic Society. He has an extensive background of editorial and national committee service and is the recipient of many awards and honors, the most recent being the Alexander von Humboldt Fellowship (1995). Dr. Wiederhorn holds a Ph.D. in chemical engineering from the University of Illinois.

Digitization and Communications Science Panel

MARY JANE IRWIN, *Chair* (see Board sketches, above)

NANCY M. AMATO is a professor in the Department of Computer Science at Texas A&M University. At the Texas A&M Parasol Laboratory, Dr. Amato conducts and directs research to develop algorithmic solutions for problems in areas such as computational biology (e.g., protein folding and drug design), motion planning (e.g., animation and robotics), computational geometry, parallel and distributed computing (e.g., performance modeling, prediction, and optimization), and computational science (e.g., physics, geosciences, neuroscience). She is the recipient of various honors, including the following: an NSF Faculty Early Career Development (CAREER) Award; a professorship for outstanding associate professors; a college-level award recognizing promising junior researchers; university, college, and departmental teaching awards; two university-level awards recognizing her contributions in support of women in computer science; and departmental service awards. She is an associate editor of the *IEEE Transactions on Robotics and Automation* and of the *IEEE Transactions on Parallel and Distributed Systems*. She regularly serves on organizing and program committees for international conferences, review panels for the NSF, and study sections for the National Institutes of Health (NIH). She is a member of the IEEE, ACM, SIAM, Intelligent Systems for Molecular Biology, and Sigma Xi. She received her Ph.D. in computer science from the University of Illinois at Urbana-Champaign, an M.S. in computer science from the University of California, Berkeley, and B.S./A.B. degrees in mathematical sciences and economics, respectively, from Stanford University.

RONALD C. ARKIN received a B.S. degree from the University of Michigan, an M.S. degree from the Stevens Institute of Technology, and a Ph.D. in computer science from the University of Massachusetts, Amherst. He then assumed the position of assistant professor in the College of Computing at the Georgia Institute of Technology, where he now holds the rank of Regents' Professor and is the director of the Mobile Robot Laboratory. From 1997 to 1998, Professor Arkin served as STINT (Swedish

Foundation for International Cooperation in Research and Higher Education) visiting professor at the Centre for Autonomous Systems at the Royal Institute of Technology (KTH) in Stockholm, Sweden. His research interests include behavior-based reactive control and action-oriented perception for mobile robots and unmanned aerial vehicles, hybrid deliberative/reactive software architectures, robot survivability, multiagent robotic systems, biorobotics, human-robot interaction, and learning in autonomous systems. Professor Arkin has over 120 technical publications to his credit in these areas. He has written a textbook entitled *Behavior-Based Robotics* and coedited a book entitled *Robot Colonies*. He serves or has served as an associate editor for *IEEE Intelligent Systems* and the *Journal of Environmentally Conscious Manufacturing* and as a member of the editorial boards of *Autonomous Robots*, *Machine Intelligence and Robotic Control* and the *Journal of Applied Intelligence*. He is the series editor for the MIT Press book series *Intelligent Robotics and Autonomous Agents*. Professor Arkin was elected to serve consecutive 3-year terms on the Administrative Committee of the IEEE Robotics and Automation Society in 1999 and 2002, and he also served on the NSF's Robotics Council for the 2001-2002 terms. In 2001, he received the Outstanding Senior Faculty Research Award from the College of Computing at Georgia Tech. He was elected a fellow of the IEEE in 2003 and is a member of the American Association for Artificial Intelligence (AAAI) and ACM.

DONALD M. CHIARULLI is a professor of computer science and computer engineering at the University of Pittsburgh. His expertise includes experimental computer architecture as well as optics and optoelectronics for dense interconnection networks. Within the context of building experimental systems, his work also includes a significant effort in the development of new design tools for the modeling and simulation of these systems. Dr. Chiarulli also holds patents in computer and related optical and optoelectronic hardware. He received his Ph.D. in computer science from Louisiana State University.

PHILLIP COLELLA (see above, under Armor and Armaments Panel)

JACK DONGARRA is University Distinguished Professor of Computer Science in the Department of Computer Science at the University of Tennessee, Knoxville, and a Distinguished Research Staff member in the Computer Science and Mathematics Division at the Oak Ridge National Laboratory. He is also an adjunct professor in computer science at Rice University. Dr. Dongarra's expertise is in high-performance computing, and he specializes in numerical algorithms in linear algebra, parallel computing, use of advanced-computer architectures, programming methodology, and tools for parallel computers. He is a fellow of the AAAS, ACM, and IEEE and a member of the NAE. Dr. Dongarra received his Ph.D. in applied mathematics from the University of New Mexico.

JOEL S. ENGEL is an NAE member and the president of JSE Consulting. His expertise includes the theory and design of cellular telecommunications systems, wireless communications, high-speed data communications, video compression, and interactive video. Dr. Engel is a senior executive with more than 40 years of experience in the communications industry. He is a retired former chief technology officer of one of the Regional Bell companies, where he was responsible for all aspects of the specification and management of the network technology. Prior to that, he spent 20 years at Bell Laboratories, where he headed the team that developed the first cellular telephone system architecture. For this achievement, Dr. Engel was awarded the Alexander Graham Bell Medal of the IEEE and the National Medal of Technology. He holds a Ph.D. in electrical engineering from the Polytechnic Institute of Brooklyn.

BRANT FOOTE, an expert in mesoscale meteorology, is a senior scientist and director of the Research Applications Program at the National Center for Atmospheric Research (NCAR). His research interests include hail, weather modification, radar meteorology, and short-range forecasting; his specialties are severe local storms and cloud physics. Since starting at NCAR in 1970, he has served as a project leader with the National Hail Research Experiment and as a senior scientist in the Field Observing Facility and the Mesoscale and Microscale Meteorology Division. He also has served as editor for the *Journal of the Atmospheric Sciences*, as a member of several national and international committees, and as the leader of a number of large field programs. Dr. Foote received his Ph.D. in atmospheric science from the University of Arizona, and he is a fellow of the American Meteorological Society.

JOSEPH HALPERN is professor and director of the Cognitive Studies Program at Cornell University. His research is concerned with representing and reasoning about knowledge and uncertainty in multiagent systems. The work uses tools from logic (particularly modal logic and the idea of possible-worlds semantics), probability theory, distributed systems, game theory, and artificial intelligence, and it contributes to the understanding of these areas as well. Some themes of his current research include defining useful notions of explanation in probabilistic systems, providing foundations for useful qualitative notions of decision theory, and applying ideas of decision theory to constructing algorithms in asynchronous distributed systems.

BRUCE B. HICKS is director of the National Oceanic and Atmospheric Administration's Air Resources Laboratory. His expertise is in atmospheric physics and meteorology, and he has most recently performed research in micrometeorology, air-surface exchange, and planetary boundary layer studies. Before taking his current position in 1989, Mr. Hicks served in a number of positions, including service as director of the Atmospheric Turbulence and Diffusion Division of the Air Resources Laboratory in Oak Ridge, Tennessee, and as a meteorologist and section head in atmospheric physics at the Argonne National Laboratory. Earlier, he was a senior research scientist at the Division of Atmospheric Physics of the Australian Commonwealth Scientific and Industrial Research Organization. Mr. Hicks is a graduate of the Universities of Tasmania and Melbourne in Australia and a member of the Royal Meteorological Society, the AMS, and the American Geophysical Union.

FRANK A. HORRIGAN retired as the technical adviser of the Technology Development Group for Sensors and Electronic Systems at Raytheon Systems. He is an expert in radar and sensor technologies. Dr. Horrigan, a theoretical physicist, has more than 40 years of experience in advanced electronics, electro-optics, and computer systems. He has a wide general knowledge of all technologies relevant to military systems, as well as extensive experience in planning and managing independent R&D investments and in projecting future technology growth directions. Dr. Horrigan is a member of the APS and the AAAS, and he also serves on the National Research Council's Naval Studies Board. He holds a Ph.D. in theoretical physics from Harvard University.

LESLIE P. KAELBLING (panel member in 2003) is a professor of computer science and engineering at MIT and a member of the MIT Artificial Intelligence Laboratory. Dr. Kaelbling has extensive expertise in artificial intelligence, including software agents, factories, and collections of transportation assets. She is the author of numerous papers, five book chapters, and one book and the editor of another book. She also has been an active member of a number of professional societies and has been involved with related professional journals. Before coming to MIT, Dr. Kaelbling held positions at Brown University, Harvard University, Teleos Research, SRI International, and Stanford University. She holds a Ph.D. in computer science from Stanford University.

DANIEL E. KODITSCHEK is a professor in the Department of Electrical Engineering and Computer Science at the University of Michigan. His current research focuses on the following areas: sensor-driven, dynamically dexterous robot manipulation (developing machine capability to react with dexterity to the environment); learning piecewise linear functional approximants (approximating an unknown function from a finite set of discrete input-output data); computational neuromechanics (developing novel and experimentally refutable hypotheses about the control strategies in insect locomotion, toward increased understanding of natural strategies in an attempt to impose control over live-animal locomotion); and the Computational Neuromechanics Hexapod Project, which aims to develop a six-legged robot, capable of achieving a wide variety of dynamically dexterous tasks, such as walking, running, leaping over obstacles, and climbing stairs, with a single autonomous platform.

PETER KOGGE is the associate dean of engineering for research and also holds the McCourtney Chair in Computer Science and Engineering (CSE) at the University of Notre Dame. Before joining Notre Dame in 1994, he was with IBM, Federal Systems Division, and was appointed an IEEE fellow in 1990 and an IBM fellow in 1993. In 1977, he was a visiting professor in the Electrical and Computer Engineering Department at the University of Massachusetts, Amherst. From 1977 through 1994, he was also an adjunct professor in the Computer Science Department of the State University of New York at Binghamton. In the summers since 1997, he has been a distinguished visiting scientist at the Center for Integrated Space Microsystems at the Jet Propulsion Laboratory (JPL). He is also the Research Thrust Leader for Architecture in Notre Dame's Center for Nano Science and Technology. For the 2000-2001 academic year, he was the Interim Schubmehl-Prein Chairman of the CSE Department at Notre Dame. Since the fall of 2003, he has also been a concurrent professor of electrical engineering. His research interests are in advanced computer architectures using unconventional technologies such as Processing-in-Memory and nanotechnologies such as Quantum dot Cellular Automata (QCA).

VIJAY KUMAR received his M.Sc. and Ph.D. in mechanical engineering from the Ohio State University in 1985 and 1987, respectively. He has been on the faculty in the Department of Mechanical Engineering and Applied Mechanics, with a secondary appointment in the Department of Computer and Information Science, at the University of Pennsylvania since 1987. He is currently a full professor and the deputy dean for research in the School of Engineering and Applied Science. Dr. Kumar also directs the GRASP Laboratory, a multidisciplinary robotics and perception laboratory with 8 faculty and 50 students and staff. He is a fellow of the ASME, a senior member of the IEEE, and a member of Robotics International, Society of Manufacturing Engineers. He has served on the editorial board of the *Journal of the Franklin Institute*, the *IEEE Transactions on Robotics and Automation,* and the *ASME Journal of Mechanical Design*. He is the recipient of the 1991 NSF Presidential Young Investigator award, the 1997 Freudenstein Award for significant accomplishments in mechanisms and robotics, and the 2004 Kayamori Automation Best Paper Award. Dr. Kumar is an expert on multirobot control, sensing, and coordination and has extensive experience working on theoretical and applied projects in robotics. He has led DARPA projects on multirobot control and coordination (MARS, MARS 2020), vision-based control and navigation for DARPA Tactical Mobile Robotics (TMR), Army Research Office (ARO) Multidisciplinary University Research Initiative (MURI) efforts, and U.S. Department of Energy (DOE) and NSF traineeships for graduate education.

MITCHELL P. MARCUS holds the RCA Chair of Artificial Intelligence in the Department of Computer and Information Science as well as an appointment in the Department of Linguistics at the University of Pennsylvania. His expertise is in artificial intelligence, with a primary focus on statistical natural language processing and the preparation of annotated corpora for use in training statistical algorithms. He was the principal investigator for the Penn Treebank Project. He is a fellow of the AAAI and a past president of the Association for Computational Linguistics. Dr. Marcus holds a Ph.D. in electrical engineering and computer science from MIT.

RICHARD T. McNIDER is professor emeritus of mathematics, professor emeritus of atmospheric science, and distinguished professor emeritus of science at the University of Alabama in Huntsville. His expertise includes meteorology and mathematical modeling of geophysical phenomena, with areas of application ranging from air pollution modeling, to ocean modeling, to thunderstorm initiation, to model assimilation of satellite data. He is a fellow of the American Meteorological Society and previously served as director of the National Space Science and Technology Center. Dr. McNider has received numerous prestigious honors and awards and has consulted for a number of companies, national laboratories, and universities. He received his Ph.D. in environmental science from the University of Virginia.

JIMMY K. OMURA is an NAE member and retired chief technical officer of Cylink Corporation, a company that he founded. His expertise includes the analysis and design of communications systems, coding theory, data compression and rate distortion theory, digital radio techniques, spread spectrum systems, satellite communications systems, and cryptography. Dr. Omura is coauthor of the textbooks *Principles of Digital Communication and Coding* and *Spread Spectrum Communications, Volumes I, II,* and *III*. He is also a fellow of the IEEE. He received his Ph.D. from Stanford University.

CHARLES F. REINHOLTZ, Alumni Distinguished Professor of Mechanical Engineering at the Virginia Polytechnic Institute and State University, earned his Ph.D. from the University of Florida. He is the coauthor of *Mechanisms and Dynamics of Machinery*, a popular textbook published by John Wiley. He holds two U.S. patents and has authored or coauthored more than 100 papers in the areas of kinematics, robotics, and unmanned vehicle systems. Professor Reinholtz is a recipient of the Alumni Teaching Award and the William E. Wine Award for outstanding teaching, and he is past chair of Virginia Tech's Academy of Teaching Excellence. He is a former holder of the W.S. White Chair for Innovation in Engineering Education and former assistant department head in mechanical engineering. He also has received the NSF Presidential Young Investigator Award and the ASME National Faculty Advisor Award. Professor Reinholtz has served as faculty adviser to the Virginia Tech student section of the ASME since 1988. He is also the adviser to the Virginia Tech Mini Baja Team (3 years), Human Powered Vehicle Team (3 years), Autonomous Vehicle Team (9 years), and DARPA Grand Challenge Team (1 year).

DENNIS W. THOMSON (see Board sketches, above)

DAVID WALTZ is director of the Center for Computational Learning Systems at Columbia University. Before going to Columbia, Dr. Waltz was chief science officer of NEC Laboratories America (2002-2003), president of the NEC Research Institute (2000-2002), and vice president for computer science research (1993-2000). He was president of the AAAI from 1997 to 1999 and a board member of the Computing Research Association from 2000 to 2004. He is a fellow of the ACM, a fellow of the AAAI, a senior member of the IEEE, and former chair of ACM SIGART (Special Interest Group on Artificial

Intelligence). Before moving to NEC, Dr. Waltz directed the data mining and text retrieval effort at Thinking Machines Corporation for 9 years, following 11 years on the faculty at the University of Illinois at Urbana-Champaign. While at Thinking Machines, Dr. Waltz also was a professor of computer science at Brandeis University. He received all of his degrees from MIT. His thesis on computer vision originated the field of constraint propagation, and, with Craig Stanfill, he originated the field of memory-based reasoning. His research interests have also included massively parallel information retrieval, data mining, learning, and automatic classification with applications in protein structure prediction, and natural language processing.

Sensors and Electron Devices Panel

DWIGHT C. STREIT, *Chair* (see Board sketches, above)

HENRY E. BASS is the F.A.P. Barnard Distinguished Professor in the Physics Department and director of the National Center for Physical Acoustics at the University of Mississippi. Dr. Bass is a widely recognized expert in acoustics, with experience that includes research in the fields of physical acoustics and molecular energy transfer in gases. Since joining the physics faculty in 1970, Dr. Bass has served in many positions at the University of Mississippi. He also has served in an advisory capacity for a number of organizations. He is a fellow of the Acoustical Society of America (ASA) and a member of many other highly respected organizations, including Sigma Pi Sigma, Phi Kappa Phi, Sigma Xi, the Physical Acoustics Technical Committee of the ASA, and NATO Research Technical Group TG 25. Dr. Bass received his Ph.D. in physics from Oklahoma State University.

ROBERT W. BRODERSEN (see Board sketches, above)

ELTON J. CAIRNS is a professor of chemical engineering at the University of California, Berkeley, and head of the Berkeley Electrochemical Research Center of Lawrence Berkeley National Laboratory. He served as associate laboratory director from 1978 to 1996. In the field of electrochemistry, he has expertise in electrochemical energy conversion, thermodynamics, transport phenomena, molten salts, liquid metals, and surface chemistry. Previously, Dr. Cairns held positions with the GM Research Laboratories, where he was assistant head of the Electrochemistry Department; the Argonne National Laboratory, where he established molten salt battery and fuel cell programs; and the General Electric Research Laboratory, where he developed a variety of fuel cells. He has received a number of awards throughout his distinguished career. He is a fellow (and past president, 1989-1990) of the Electrochemical Society and the American Institute of Chemists and a member of the American Institute of Chemical Engineers, the AAAS, ACS, and the International Society of Electrochemistry (president, 1999-2000). Dr. Cairns has served on many governmental advisory committees, including the National Battery Advisory Committee and the NRC Committee on Electric Power for the Dismounted Soldier. He received his Ph.D. in chemical engineering from the University of California, Berkeley.

L. RICHARD CARLEY is the STMicroelectronics Professor of Engineering in the Electrical and Computer Engineering Department at Carnegie Mellon University. His expertise includes the design of analog circuits and systems for mixed-signal integrated circuits (ICs), the development of computer-aided design tools to support the analog IC design flow, and the design of integrated microelectromechanical systems. Dr. Carley served as the associate director for electronic subsystems for the Data Storage Systems Center at Carnegie Mellon from 1990 to 1999. He has also worked for MIT's Lincoln

Laboratory and has been a consultant for numerous companies. In addition, he was a cofounder of NeoLinear, an analog design automation tool provider, and a cofounder of IC Mechanics, a MEMS IC company. Dr. Carley has been granted 12 patents, and he has authored or coauthored more than 120 technical papers and more than 20 books and book chapters. He has won several prestigious awards and is a fellow of the IEEE. He received his Ph.D. in electrical engineering from MIT.

ARTHUR GUENTHER is a leading expert on directed-energy weaponry, including lasers, microwaves, particle beams, and pulsed-power technology. His work in nuclear weapons simulation was concerned with the response of materials to adverse environments. Prior to joining the University of New Mexico, Dr. Guenther served as chief scientist for the Air Force Weapons Laboratory (1974-1988), as chief scientist for advanced defense technologies at Los Alamos National Laboratory, and as scientific adviser for laboratory development at Sandia National Laboratories (1991-1997). He is the recipient of numerous awards from the IEEE, the Laser Institute of America, and state and federal governments. Dr. Guenther was science adviser to three governors of New Mexico (1988-1993) and is a fellow of the Optical Society of America, the Laser Institute of America, the IEEE, the International Society for Optical Engineers (SPIE), and the Directed Energy Professional Society. Dr. Guenther is an active consultant to Department of Defense organizations, Department of Energy national laboratories, and other groups. He is past president of the International Commission for Optics and a member of the Russian Academy of Sciences (Ural Division).

ALFRED O. HERO is a professor in the Department of Electrical Engineering and Computer Science, the Department of Biomedical Engineering, and the Department of Statistics at the University of Michigan. His expertise includes statistical signal and image processing, detection and estimation theory, bioinformatics, and tomographical imaging. He has held visiting positions at the University of Nice, Ecole Normale Supérieure de Lyon, Ecole Nationale Supérieure des Télécommunications, Scientific Research Laboratories of the Ford Motor Company, Ecole Nationale des Techniques Avancées, Ecole Supérieure d'Electricité, and MIT Lincoln Laboratory. In addition, throughout his career, Dr. Hero has served the IEEE in various leadership roles and has received a number of prestigious honors, awards, and fellowships, including an IEEE Signal Processing Society Meritorious Service Award and the IEEE Third Millennium Medal. He is a fellow of the IEEE and was named a William Clay Ford Fellow by Ford Motor Company in 1992. He was chair of the USNC URSI (United States National Committee of the International Union of Radio Science) Commission C and is president-elect of the IEEE Signal Processing Society. He received his Ph.D. in electrical engineering from Princeton University.

NARAIN G. HINGORANI is an independent consultant and a member of the NAE. His expertise includes high power conditioning and electronics. Dr. Hingorani established a private consulting service after 20 years of progressive advancement at the Electric Power Research Institute. He also has served in a number of other capacities, including chair of the CIGRE (International Council on Large Electric Systems) Study Committee 14 (High Voltage DC Links and AC Power Electronic Equipment), member of the board of directors of the IEEE Power Engineering Society, and member of the IEEE Foundation. He has authored more than 150 papers and articles and has received prestigious awards for his outstanding work, including the Uno Lamm Award from the IEEE Power Engineering Society (1985) and the Lamme Gold Medal from the IEEE (1996). He also is a fellow of the IEEE. Dr. Hingorani holds a Ph.D. in electrical engineering from the University of Manchester Institute of Science and Technology.

KEITH H. JACKSON is the associate director of the Center for X-ray Optics in the Materials Science Division, Lawrence Berkeley National Laboratory. Dr. Jackson's expertise is in semiconductor fabrication. He holds a Ph.D. in physics from Stanford University. Dr. Jackson is a member of the APS, IEEE, Sigma Xi, SPIE, and the National Society of Black Physicists, and he is a member of the Technical Advisory Board of the Center for the Study of Terrestrial and Extraterrestrial Atmospheres at Howard University.

LINDA P.B. KATEHI is the John A. Edwardson Dean of Engineering and a professor of electrical and computer engineering at Purdue University. Before joining Purdue in 2002, she had joined the faculty of the Electrical Engineering and Computer Science Department of the University of Michigan, Ann Arbor, in 1984 as an assistant professor and moved to the levels of associate professor and professor. She served in many administrative positions, including director of graduate programs in the College of Engineering, elected member of the College Executive Committee, associate dean for graduate education, and associate dean for academic affairs. Her expertise includes microwave, millimeter printed circuits; the development and characterization of micromachined circuits for microwave, millimeter-wave, and submillimeter-wave applications, including MEMS switches, high-Q evanescent mode filters and MEMS devices for circuit reconfigurability. Dean Katehi has received many prestigious awards throughout her career. She is a fellow of the IEEE and a member of IEEE Antennas and Propogation Society (AP-S), IEEE Microwave Theory and Techniques Society (MTT-S), Sigma Xi, Hybrid Microelectronics, and URSI Commission D. She was a member of AP-S ADCOM and is serving currently on the IEEE MTT-S ADCOM and on a number of advisory committees to NSF, NASA, and the DOD. Also, Dean Katehi has been an associate editor for the *IEEE Transactions on Microwave Theory and Techniques* and the *IEEE Transactions on Antennas and Propagation*. She has been the author or coauthor of 450 technical papers and holds 11 patents. She received the B.S.E.E. degree from the National Technical University of Athens, Greece, and the M.S.E.E. and Ph.D. degrees from the University of California at Los Angeles.

TIMOTHY N. KRABACH is program manager of the Life Detection Science and Technology Program Office at the Jet Propulsion Laboratory. His JPL activities include oversight of the laboratory's developments of in situ sensors and nanotechnology for planetary missions, NASA crewed vehicles, and NASA's aviation security programs, as well as national security applications. Dr. Krabach has an extensive background in both devices and systems; he was the NASA lead for the core technology program in Breakthrough Sensor and Instrument Technologies, and he is also the NASA-designated lead for Advanced Miniaturization and for the Microspacecraft Grand Challenge of the National Nanotechnology Initiative. Throughout his career, Dr. Krabach has received numerous awards for his technical achievements and leadership. He received his Ph.D. in physics from the University of Illinois at Urbana-Champaign.

KAREN W. MARKUS has a background in business and technology management as well as technical expertise in MEMS technologies. She is currently the president of Zeus Strategies, LLC, a consulting company focused on corporate technology strategies, mergers and acquisitions, and disruptive technologies. From 2000 to 2003, she was vice president of technology strategy for JDS Uniphase Corporation. Prior to that, Ms. Markus served as vice president and chief technical officer for Cronos Integrated Microsystems, Inc., a MEMS research and development company acquired by JDS Uniphase in 2000. She served as chair of the board and executive director of the HI-MEMS Alliance—Research Triangle Park, North Carolina, for the period 1993 to 1997, and from 1992 to 1999 was director of the MEMS

Technology Applications Center at Microelectronics Center of North Carolina (MCNC), a family of private, nonprofit corporations created to drive technology-based economic development and job creation throughout North Carolina. From 1984 to 1989, Ms. Markus was a staff engineer for TRW Space and Defense Sector. She has been a member of several other NRC study groups, including the Committee on Advanced Materials and Fabrication Methods for Microelectromechanical Systems. Ms. Markus has a B.S. in electrical engineering from the University of Southern California at Los Angeles and has participated in a number of management training programs, including the Executive Program in Corporate Strategy at the MIT Sloan School of Management.

RICHARD S. MULLER (panel chair in 2003; see Board sketches, above)

DAVID C. MUNSON, JR., is chair of the Electrical Engineering and Computer Science Department at the University of Michigan, Ann Arbor. He was formerly a professor in the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. His research interests are in the general area of signal and image processing, with current work focused on radar imaging, passive millimeter-wave imaging, lidar imaging, tomography, and interferometry. He has held summer positions in digital communications and speech processing, and served as a consultant in synthetic aperture radar to the Lockheed Palo Alto Research Laboratory. Dr. Munson is a fellow of the IEEE. Among numerous other honors and awards, he has received the Society Award from the IEEE Signal Processing Society and an IEEE Third Millennium Medal. He is a former president of the IEEE Signal Processing Society and the founding editor in chief of the *IEEE Transactions on Image Processing*. He currently is serving on the editorial board of *The Proceedings of the IEEE* and chairing the IEEE Kilby Signal Processing Medal Committee. Dr. Munson received his Ph.D. in electrical engineering from Princeton University.

P. PAUL RUDEN is a professor in the Department of Electrical and Computer Engineering at the University of Minnesota. His expertise includes electronic properties of large-gap semiconductor materials and devices, polarization effects in III-V heterostructures, properties of organic semiconductor materials and devices, modeling of field-effect transistors, modeling of photodetectors and related optoelectronic devices, and quantum effects in nanometer-scale semiconductor structures. In addition, Dr. Ruden also has consulted for Honeywell, Inc., the Naval Research Laboratory, and the Los Alamos National Laboratory (LANL).

JOHN F. SCHULTZ is a senior program manager with Battelle, managing infrared research and applications programs at the Pacific Northwest National Laboratory (PNNL). His PNNL activities include analyzing the chemical signatures of nuclear and chemical weapons production processes, developing second-generation spectroscopic chemical detection techniques, and developing quantum cascade lasers to support these techniques. Prior to joining Battelle in 1998, Dr. Schultz worked at the LANL and served as a field artillery officer and research program manager in the U.S. Army. At Los Alamos, Dr. Schultz led the Department of Energy's CALIOPE CO_2 Differential Absorption Lidar (DIAL) project. In the Army, his duties included serving as the Army's technical manager for the Strategic Defense Initiative's Free Electron Laser program. A graduate of the U.S. Military Academy at West Point, Dr. Schultz holds a Ph.D. in physics from Stanford University. He is also a current member of the ARLTAB Survivability and Lethality Analysis Panel.

FRITZ STEUDEL is a consultant to and former employee of Raytheon Company. Mr. Steudel has had a distinguished career as a system designer and architect of major phased-array radar systems, making contributions to such systems as PAVE PAWS, BMEWS, Cobra Dane, and Cobra Judy. He also has been the system architect for the Ballistic Missile Defense Organization's (BMDO's) ground-based radar family of radars. One specific contribution that he has made to the field is the capability for a phased-array radar to efficiently track thousands of targets. Mr. Steudel has been awarded six patents, with another pending; he was the recipient of Raytheon's first Excellence in Technology Award, and he is a fellow of the IEEE. He also received the IEEE Dennis J. Picard Medal for Radar Technology and Applications (2001). In addition, he has participated in a number of advisory studies, including studies by the Defense Science Board. Mr. Steudel holds an M.S.E.E. degree from Northeastern University.

Soldier Systems Panel

DOUGLAS H. HARRIS, *Chair* (see Board sketches, above)

DONALD B. CHAFFIN is a member of the NAE, the R.G. Snyder Distinguished University Professor, and the G. Lawton and Louise G. Johnson Professor of Industrial and Operations Engineering, Biomedical Engineering, and Occupational Health at the University of Michigan. He was elected into the NAE "for fundamental engineering contributions to and leadership in occupational biomechanics and industrial ergonomics." Software resulting from his work is used in companies and universities throughout the world to evaluate the risk of injuries due to overexertion in the performance of a variety of common manual tasks, and to assist in designing workplaces and vehicles to better accommodate a diverse population. Dr. Chaffin is the founder and director of the Human Motion Simulation Laboratory at the University of Michigan. This laboratory is currently supported by GM, Ford, DaimlerChrysler, International Truck, Lockheed Martin, the U.S. Postal Service, and the U.S. Army's Tactical Command to develop and implement software modules to predict human motions and biomechanical limitations in computer-aided design simulations that would affect the design of future vehicle and workplace systems. Dr. Chaffin has received numerous prestigious awards and has had 105 peer-reviewed journal articles and 23 book chapters published. He has coauthored five books, the latest entitled *Digital Human Modeling for Workplace and Vehicle Design*. He received his Ph.D. in industrial engineering from the University of Michigan.

DENNIS G. FAUST is the training lead for a major defense systems development and integration program at Lockheed Martin's Management and Data Systems Division; he has an extensive background in education and training. Dr. Faust has applied his education to the broad areas of personnel and instructional psychology, with a focus on training and education, including related performance assessment, research, integrated logistics support, and human factors. His experience includes work with the U.S. military services, IBM, RCA, the Federal Aviation Administration, the U.S. Department of State, and schools and colleges. Dr. Faust is active in professional groups such as the American Psychological Association and the Potomac Chapter, Human Factors and Ergonomics Society, and he has served as contributor to publications such as *Encyclopedia of Psychology* (John Wiley). He received his Ed.D. in counseling and educational psychology, with supporting fields in research and psychometrics, from the University of Virginia.

MARTHA GRABOWSKI (panel member in 2003) is professor and director of the Information Systems program in the Business Department at LeMoyne College in Syracuse, New York, and research professor in the Department of Decision Sciences and Engineering Systems at Rensselaer Polytechnic Institute. Her research interests include the impact of technology on people and systems, embedded intelligent real-time systems, human and organizational error, and risk mitigation in safety-critical settings. Her research teams have developed and evaluated a series of embedded intelligent real-time ship's piloting systems and have undertaken a series of major risk assessments over the past 10 years. She is currently investigating the impact of new security technology on vessels, operators, and the marine transportation system on the St. Lawrence Seaway, as well as the role of human and organizational error in large-scale medical systems. Dr. Grabowski is a member of the American Bureau of Shipping. She also serves on the NRC's Transportation Research Board/Marine Board, as well as on the NRC's standing Committee on Human Factors. She is currently chairing an NRC Marine Board committee examining shipboard display of Automatic Identification System information. Earlier in her career, Dr. Grabowski served as a shipboard merchant marine officer and spent 10 years at General Electric as a marketing and advanced programs manager. Her last position at GE was as program integration manager for information systems and artificial intelligence research programs at GE's Corporate Research and Development Center. She received her doctorate from Rensselaer Polytechnic Institute.

ROBERT T. HENNESSY, president of Monterey Technologies, has been involved in applied behavioral research and development since receiving his Ph.D. in experimental psychology from the Pennsylvania State University in 1972. His primary areas of interest are vision, perception, and human performance. He has performed and managed numerous projects on visual displays, simulation, and military workstation design, primarily for aviation systems. In 1980, Dr. Hennessy became the first study director for the NRC's Committee on Human Factors. He is the author of more than 40 scientific articles and technical reports. He is a fellow of the American Association for the Advancement of Science.

ROBERT A. HENNING is an associate professor of industrial/organizational psychology in the Psychology Department at the University of Connecticut. He specializes in human factors and applied psychophysiology and is currently the program director of a doctoral training program in occupational health psychology sponsored by the National Institute of Occupational Safety and Health (NIOSH). He received his B.S. in psychology, M.S. in biomedical engineering, and Ph.D. in industrial engineering from the University of Wisconsin-Madison. Dr. Henning has performed research on work patterns and schedules, social interaction and teamwork, comparisons of team and individual performance, computer-supported cooperative work, human interaction with automated systems, behavioral toxicology, and the social psychophysiology of teamwork. He currently serves as president of Psychophysiology in Ergonomics, a technical group of the International Ergonomics Association. He is a board-certified professional ergonomist and former NRC/NIOSH postdoctoral fellow at NIOSH.

BONNIE ELIZABETH JOHN is an associate professor in the Human-Computer Interaction Institute, School of Computer Science, Carnegie Mellon University. Dr. John also is affiliated with the Psychology Department at Carnegie Mellon. She has a background in mechanical engineering and cognitive psychology and works within a unified theory of cognition to develop models of human performance that are applicable to the design of computer systems. In addition to her primary research interest in cognitive modeling, Dr. John is also currently working on the links between usability and software architecture. She also serves on the NRC's Committee on Human Factors.

JOHN D. LEE is an associate professor in the Department of Mechanical and Industrial Engineering at the University of Iowa. He received a B.A. in psychology and B.S. in mechanical engineering from

Lehigh University and an M.S. in industrial engineering and Ph.D. in mechanical engineering from the University of Illinois at Urbana-Champaign. His experience also includes positions as researcher and deputy director at the Battelle Human Factors Transportation Center. Dr. Lee has 10 years of research and consulting experience aimed at matching human capabilities to the demands of technologically intensive systems. This research addresses human error and performance in a broad range of application domains from process control and the maritime industry to driving. In the driving domain, he has been deeply involved in research addressing in-vehicle information systems. This research, involving focus groups, development of analytic techniques, field studies of drivers, and simulator-based experiments, has resulted in human factors guidelines for in-vehicle information systems ranging from navigation devices to collision-avoidance systems. In the area of process control, Dr. Lee is investigating the factors governing appropriate reliance on automation.

ERIC R. MUTH is an associate professor in the Psychology Department at Clemson University. His current work focuses on stress in high-workload environments, particularly the stress of motion and acceleration and the effect of stress on the gastrointestinal system. He currently has 11 first-author publications dealing with a focus on nausea and the electrogastrogram (EGG, a noninvasive measure of gastric-myoelectrical activity). He is an expert in using the EGG to study nausea and motion sickness, and he led an effort to develop a nausea profile questionnaire that has been used in studies of chemotherapy-induced nausea, motion sickness, and functional dyspepsia. Before joining the Clemson faculty, Dr. Muth served as an aerospace experimental psychologist at the Naval Aerospace Medical Research Laboratory in Pensacola, Florida, completing studies of naval significance related to night vision, motion adaptation syndrome, and the use of flight simulators in the shipboard environment. He received his Ph.D. in psychology from the Pennsylvania State University.

FRANK E. RITTER received his B.S.E.E. (with honors) from the University of Illinois at Urbana-Champagne and his M.S. in psychology and Ph.D. in artificial intelligence and psychology from Carnegie Mellon University. He has been an associate professor in information science and technology at the Pennsylvania State University since 1999, as well as having appointments in psychology and in computer science and engineering. He has created software, tutorials, and methodology for cognitive modeling, particularly with the Soar and ACT-R architectures. Dr. Ritter has published widely in the areas of cognitive modeling, artificial intelligence, and psychology. He is on the editorial board of *Human Factors* and is the series editor for *Advances in Cognitive Models and Architectures* (Oxford University Press). Dr. Ritter's research has been funded by organizations including the Office of Naval Research, the Defense Advanced Research Projects Agency, the Defense Evaluation and Research Agency (United Kingdom), and the U.K. Joint Council Initiative on Cognitive Science and Human Computer Interaction, as well as corporations in the United States and Europe.

Survivability and Lethality Analysis Panel

DAVID R. FERGUSON, *Chair* (see Board sketches, above)

ROMESH C. BATRA is the Clifton C. Garvin Professor of Engineering Science and Mechanics at the Virginia Polytechnic Institute and State University. He has extensive experience in computational mechanics (with well over 200 publications), including studies of penetration and impact. His research interests include computational solid mechanics, adiabatic shear banding, penetration and impact problems, metal forming, and "smart" materials. Dr. Batra is a fellow of the American Society of Mechanical

Engineers, the American Society for Engineering Education, the Society of Engineering Science, and the American Academy of Mechanics. He is the recipient of the Humboldt Award for Senior Scientists (1992) and the Eric Reissner Medal (2000) from the International Society of Computational Engineering and Sciences for contributions to the mechanics of penetration. He was the president of the SES for the 1996 calendar year. Dr. Batra received his Ph.D. in mechanics from the Johns Hopkins University.

JOHN D. CHRISTIE, a senior fellow at the Logistics Management Institute, has an extensive background in Department of Defense (DOD) acquisition policy and program analysis. From 1989 to 1993, he was the director of acquisition policy and program integration for the Office of the Under Secretary of Defense (Acquisition). In this role, he directed the preparation of a comprehensive revision of all defense acquisition policies and procedures, resulting in the cancellation and consolidation of 500 prior separate issuances; he also prepared decision papers on major acquisition programs and advised the under secretary on resource allocation issues. During 1976 and 1977, as the assistant administrator for energy information and analysis at the Federal Energy Administration, he was responsible for forecasting supply and demand for all fuels and consuming sectors of the U.S. economy. From 1966 to 1976, Dr. Christie served in a number of positions in the Office of the Assistant Secretary of Defense for Systems Analysis (renamed Program Analysis and Evaluation), where his last assignment was as principal deputy assistant secretary. In that capacity, he provided advice to various secretaries of defense on acquisition programs and other major DOD resource allocation issues. He has served on numerous DOD advisory committees and a number of NRC committees.

STEPHEN D. CROCKER (panel member in 2003) is the chief executive officer and cofounder of Shinkuro, building peer-to-peer collaboration products and systems. Dr. Crocker was a cofounder and chief executive officer of Longitude Systems, which built back-office software for communications service providers, and he was one of the founders and chief technology officer of CyberCash, which pioneered payments over the Internet. In the late 1960s and early 1970s, he was part of the team that developed the protocols for the ARPAnet and laid the foundation for today's Internet. He also organized the Network Working Group, which was the forerunner of the modern Internet Engineering Task Force, and he initiated the Request for Comment series of notes through which protocol designs are documented and shared. Dr. Crocker has been a program manager at the Advanced Research Projects Agency (now DARPA), a senior researcher at the University of Southern California's Information Sciences Institute, the founder and director of the Computer Science Laboratory at the Aerospace Corporation, and a vice president at Trusted Information Systems. Dr. Crocker received his Ph.D. in computer science from the University of California at Los Angeles. For his work on the development of the original protocols and processes for protocol development, Dr. Crocker received the IEEE Internet Award (2002).

MARJORIEANN ERICKSONKIRK is an expert in the development of physics-based models of material behavior in the prediction of material failure, and performing risk assessment. Dr. EricksonKirk is president of Phoenix Engineering Associates, Inc., and an adjunct professor of mechanical engineering at the University of Maryland. She conducts research and consults with industry regarding fracture safety-assessment methodology for steel and other alloy components. She provides these services in the areas of assessing the integrity and durability of civil, mechanical, and marine structures fabricated from metallic materials. Specific work that Dr. EricksonKirk has performed includes developing and using integrated, predictive models of material behavior for the purpose of assessing the current status and predicting the remaining safe life, under known or expected operating and accident-event conditions, for nuclear pressure vessels and other alloy applications, including fracture safety assessment and life extension of aging aircraft and pipelines. Dr. EricksonKirk received her Ph.D. in materials science from the University of Virginia.

ARTHUR GUENTHER (panel member in 2003; see above, under Sensors and Electron Devices Panel)

DANIEL N. HELD (panel member in 2003) is the director and chief architect for networked strike in the Electronic Systems Sector of Northrop Grumman. Previously, he served as the director and chief scientist for the Joint Strike Fighter program. Before coming to his present position, he was the vice president of research, development, and advanced systems at Westinghouse's Norden Systems Division, where he was responsible for developing new radar systems and improving existing systems. He also spent 11 years at JPL as deputy manager of the group responsible for all synthetic aperture radar work conducted by NASA, and he was a principal architect of the Venus-orbiting Magellan radar. Dr. Held is the author of more than 50 technical papers and has received numerous honors and awards for his work involving sensor systems technology. He also currently serves on the Air Force Scientific Advisory Board, formerly served on the Naval Research Advisory Committee, and recently participated in a Defense Science Board Task Force, as well as serving on numerous NRC committees. Dr. Held received his Sc.D.E.E. degree from Columbia University.

MELVIN F. KANNINEN is an independent consultant and a member of the National Academy of Engineering. He is internationally recognized for his contributions to basic research in structural mechanics, materials behavior, and fracture mechanics and for his applications of these technologies to pipelines, nuclear power plants, and aircraft structures. He has had more than 30 years of research and development experience, including service at the Stanford Research Institute, Battelle, and the Southwest Research Institute. He is currently providing independent engineering consulting services to a number of industrial and governmental organizations. Dr. Kanninen has completed more than 180 technical publications, edited 6 books, and coauthored the well-regarded textbook *Advanced Fracture Mechanics*.

RICHARD LLOYD is a senior principal engineer fellow at Raytheon Company. He is recognized around the world as a leader in antiballistic missile warhead design and lethality analysis. Mr. Lloyd has written two best-selling books on these topics for the American Institute of Aeronautics and Astronautics; both texts are taught at the Naval Postgraduate School. He has assembled a team at Raytheon that is highly skilled in performing hydrocode damage modeling, chemical/biological ground effects, endgame lethality analysis, and explosive dynamics and hypervelocity impact modeling.

TERESA F. LUNT, an expert in information security/information warfare, is a principal scientist and manager of the Computer Science Laboratory at the Palo Alto Research Center (PARC). Before joining PARC, she was the associate director of the Computer Science Laboratory at SRI International and an assistant director and program manager at DARPA. At SRI International, she was responsible for building new research programs in distributed computing. At DARPA, Ms. Lunt developed and managed the Information Survivability program, was instrumental in developing the Information Assurance program, and served as DARPA's point of contact for coordination with the National Security Agency and other DARPA programs. She is a member of IEEE, the IEEE Computer Society, the Association for Computing Machinery, the International Federation for Information Working Group 11.3 on database security and Working Group 10.4 on reliability, and of the IEEE Computer Society Technical Committee on Security and Privacy. In addition, she is a member of the Air Force Scientific Advisory Board and the recipient of a number of prestigious awards. Ms. Lunt received her M.A. degree in applied mathematics from Indiana University.

JOHN McHUGH is a senior member of the technical staff at the CERT Coordination Center (CERT/CC) of the Software Engineering Institute at Carnegie Mellon University. He has broad experience in computer security as a researcher and as a consultant to government and industry. Dr. McHugh is a former chair of the IEEE Computer Society Technical Committee on Security and Privacy and the author of numerous papers in the computer security area. He also has developed tutorials in formal verification and covert channel analysis, and his academic research and teaching are in the fields of computer security and software engineering. Dr. McHugh is a member of IEEE and the IEEE Computer Society. He received his Ph.D. in computer science from the University of Texas.

MAX D. MORRIS is a professor in the Departments of Statistics and of Industrial and Manufacturing Systems Engineering at Iowa State University. His expertise includes statistics, experimental design, spatial sampling and modeling, change detection techniques, and the design and analysis of computer experiments. Before joining the faculty at Iowa State in 1998, he held faculty positions at the University of Texas Health Sciences Center and Mississippi State University, and he was a senior research scientist and statistics group leader at the Oak Ridge National Laboratory. He is a fellow of the American Statistical Association and a former editor of the journal *Technometrics*. Dr. Morris received his Ph.D. in statistics from the Virginia Polytechnic Institute and State University.

JOHN REESE is an independent consultant who has been involved in the technical assessment of the survivability and vulnerability of U.S. and foreign systems, as well as countermeasures, for more than 30 years. He is a member of the Army Science Board and has been a National Security Agency advisory board member and consultant. Mr. Reese is retired from TRW and GTE and was the director of both the TRW Electromagnetic System Laboratory's R&D program and the GTE Electronic Defense Laboratories' R&D program. Additionally, he was the director of both GTE's and TRW's Intelligence and Threat Assessment Directorates as well as being responsible for strategic planning at both organizations. He also served on the Information Systems Technology panel for the 2002 DOD Technical Area Review and Assessment program reviews.

JOHN F. SCHULTZ (see above, under Sensors and Electron Devices Panel)

JOHN C. SOMMERER (panel member in 2003; see Board sketches, above)

JACK L. WALKER is currently a consultant working on sensor systems and the analysis of ballistic missile defense systems in support of government agencies. He retired from Veridian ERIM International in 2000 as chief scientist responsible for R&D activities in imaging and information processing technology with applications for defense, industry, and the environment. He was elected to the NAE for his "contributions to the invention, development, and deployment of radar remote sensing systems" and is recognized as a major contributor and expert on synthetic aperture radar systems and processing methods. Dr. Walker is a fellow of the IEEE and received his Ph.D. from the University of Michigan.

DONALD C. WUNSCH is former chief scientist of BDM Corporation and a current employee of Heartbeat Medical Corporation (a subsidiary of Printron, Inc.). Dr. Wunsch's expertise includes directed energy (involving source development and lethality analysis and experiments), high-voltage high-power technology, optics (involving experimental and theoretical studies in nonlinear optics), nuclear weapons effects, nuclear instrumentation development and testing, plasma physics, weapons system fire control, avionics technology, reverse engineering, system and test safety, and medical treatment devices. Dr. Wunsch is a registered professional engineer. He has worked for the Air Force Weapons Laboratory both as a civilian and as a military officer, for New Mexico State University, for the Sandia National Laboratories, and for the Physical Science Laboratory. He received his doctorate in electrical engineering from New Mexico State University.

Appendix C

Panel Meeting Agendas, 2003 and 2004

AIR AND GROUND VEHICLE TECHNOLOGY PANEL

May 13-15, 2003
Cleveland, Ohio

Tuesday, May 13

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

OPEN SESSION

8:30 p.m.	Army Research Laboratory and Vehicle Technology Directorate (VTD) Overview

Wednesday, May 14

OPEN SESSION

8:15 a.m.	Welcome
8:30 a.m.	Vehicle Technology Directorate Overview
8:45 a.m.	Propulsion Overview
9:00 a.m.	Active Stall Control Engine Demonstrator Program
9:45 a.m.	Some Advanced Aerodynamic Technologies for Expanding the Turbo-Compressor Design and Operability Envelope (Compressors—UEET)
10:15 a.m.	Compressor Flow Control, Base Research and Technology
10:45 a.m.	Break
11:00 a.m.	Combustors—Ceramic Matrix Composite (CMC) Vane Subelement Fabrication
11:30 a.m.	Materials—Cooled Silicon Nitride Turbine Nozzle Vanes, VP2A15B, Monolithic Ceramic Turbine Nozzle
12:00 p.m.	“Skip-level” lunch with scientists and engineers
1:00 p.m.	Materials—Advanced Ceramic Thermal and Environmental Barrier Coatings
1:30 p.m.	Structures—Modeling Nonmetallic Inclusions in Powder Metallurgy Alloys
2:00 p.m.	Rotorcraft Drives—Improving Gear Performance Using Superfinishing
2:30 p.m.	Break
2:45 p.m.	Mechanical Components—Oil-Free Turbomachinery
3:15 p.m.	Mechanical Components—High-Temperature Magnetic Bearing for Turbomachinery

CLOSED SESSION

3:45 p.m.	Panel deliberation session

OPEN SESSION

4:15 p.m.	Wrap-up question-and-answer session
5:00 p.m.	Adjourn

CLOSED SESSION
7:00 p.m. Panel working dinner meeting

Thursday, May 15

CLOSED SESSION
8:00 a.m. Panel working breakfast meeting

OPEN SESSION
10:30 a.m. Wrap-up session with senior VTD management
12:00 p.m. Adjourn

AIR AND GROUND VEHICLE TECHNOLOGY PANEL

May 10-12, 2004
Hampton, Virginia

Monday, May 10

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Tuesday, May 11

OPEN SESSION

8:00 a.m.	Vehicle Technology Directorate (VTD) Overview
8:45 a.m.	Active Stall Control Engine Demonstration (ASCED)
9:30 a.m.	Break
9:45 a.m.	Structural Mechanics Division Overview
10:10 a.m.	Overview of VTD Support to SARAP
10:20 a.m.	Composite Skin/Stringer Debonding Analysis
10:45 a.m.	Characterization and Analysis of Delamination in Z-pin Reinforced Composites
11:10 a.m.	Influence of Z-pin Reinforcement on Strength of Composites
11:35 a.m.	Compression Strength Prediction of Impact-Damaged Composite Sandwich Panels
12:00 p.m.	Lunch
1:00 p.m.	Selectively Reinforced and Multifunctional Structures
1:30 p.m.	Interaction Between Vibration and Stability in Compressively Loaded Composite Panels
2:00 p.m.	Effects of Elastic Edge Restraints and Initial Prestress on the Buckling Response of Compression-Loaded Composite Panels
2:30 p.m.	Break
3:00 p.m.	Loads and Dynamics Division Overview
3:30 p.m.	Experimental and Analytical Investigation of a Semiarticulated Soft-Inplane Tiltrotor
4:00 p.m.	Recent Developments in NASA-ARL Piezocomposite Actuator Technology
4:30 p.m.	An Overview of the Active Twist Rotor Program
5:00 p.m.	Design of Active Twist Rotor Blades
5:30 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Wednesday, May 12

CLOSED SESSION

8:00 a.m.	Panel working breakfast meeting

OPEN SESSION

10:00 a.m.	Wrap-up with senior VTD management
12:00 p.m.	Adjourn

ARMOR AND ARMAMENTS PANEL

June 10-13, 2003
Aberdeen Proving Ground, Maryland

Tuesday, June 10

CLOSED SESSION
7:00 p.m. Panel working dinner meeting

OPEN SESSION
8:30 p.m. Welcome and Army Research Laboratory (ARL) and Weapons and Materials Research Directorate (WMRD) Overview

Wednesday, June 11

CLOSED SESSION
7:00 a.m. Panel working breakfast meeting

OPEN SESSION
8:00 a.m. Travel to Aberdeen Proving Ground (APG)
8:30 a.m. Break
8:45 a.m. Introduction and opening observations
9:00 a.m. Welcome and WMRD Overview

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

I. Vehicle Survivability

9:15 a.m. ARL Survivability Program Overview
9:45 a.m. Structural Armor
10:15 a.m. Break
10:30 a.m. Enhanced Ceramic Armor
11:00 a.m. Electromagnetic Armor
11:30 a.m. Disruption of Shaped-Charge Jets by Electromagnetic (EM) Fields
12:00 p.m. Lunch/FCS-X1 Test Plan Overview
12:30 p.m. Travel to EF14 or B1100F
12:50 p.m. View X1 Structure/Possible Test
1:35 p.m. Return to B4600

OPEN SESSION

I. Vehicle Survivability (Continued)

2:00 p.m.	Crew, Component, and Structural Survivability
2:45 p.m.	Composite Modeling
3:15 p.m.	Break
3:30 p.m.	Ceramic Armor Overview
4:00 p.m.	Modeling Ceramic Armor
4:30 p.m.	Experimental Ceramic Efforts
5:00 p.m.	Implementation of Wright's Adiabatic Shear Model
5:30 p.m.	Discussion/Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Thursday, June 12

OPEN SESSION

I. Vehicle Survivability (Continued)

7:45 a.m.	Travel to APG
8:15 a.m.	Break

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

I. Vehicle Survivability (Continued)

8:30 a.m.	APS Program Overview
9:00 a.m.	Universal Countermunition
9:30 a.m.	Infrared (IR) Prox Sensor for Universal Countermunition

OPEN SESSION

II. Personnel Survivability

10:00 a.m.	Break
10:15 a.m.	Personnel Survivability Overview
10:45 a.m.	Small Arms Ballistic Protection Technologies
11:15 a.m.	Blunt Trauma Characterization and Modeling
11:45 a.m.	Poster session
12:45 p.m.	"Skip-level" lunch with researchers
1:30 p.m.	Shear Thickening Fluids
2:00 p.m.	Future Helmet Research

III. Materials Center of Excellence

2:30 p.m.	Materials Center of Excellence Overview
2:45 p.m.	Shock-Induced Localized Amorphization in B4C
3:15 p.m.	Achieving Shear Localization in Tungsten
3:45 p.m.	Break

IV. Robotics Collaborative Technology Alliance (CTA)

4:00 p.m.	Robotics CTA Overview
4:20 p.m.	Carnegie Mellon University Work for Robotics CTA
5:00 p.m.	Vision Processing for Robotics (Sarnoff Corporation)
5:40 p.m.	Discussion/Adjourn

CLOSED SESSION

7:30 p.m. Panel working dinner meeting

Friday, June 13

CLOSED SESSION

8:00 a.m. Panel working breakfast meeting

OPEN SESSION

10:30 a.m. Wrap-up meeting with senior WRMD management
12:00 p.m. Adjourn

ARMOR AND ARMAMENTS PANEL

May 24-25, 2004
Aberdeen Proving Ground, Maryland

Monday, May 24

CLOSED SESSION

7:00 a.m.	Panel working breakfast meeting

OPEN SESSION

8:30 a.m.	Travel to Aberdeen Proving Ground (APG)
9:00 a.m.	Break
9:15 a.m.	Introduction and Opening Observations
9:30 a.m.	Welcome and Weapons and Materials Research Directorate (WMRD) Overview
9:45 a.m.	Overview of Materials Research Approach
10:15 a.m.	Use of Tailored Molecules to Control the Interface Between Organic Films and Metals
10:45 a.m.	Break
11:00 a.m.	Thin-Film Dielectric Materials Development
11:30 a.m.	Permselective Membranes
12:00 p.m.	Photonic Bandgap Materials Through Microbubbling
12:30 p.m.	Lunch/laboratory tour/poster session
2:30 p.m.	Instrumented Indentation Mechanics
3:00 p.m.	Transparent Materials Development
3:30 p.m.	Armor Ceramic Development
4:00 p.m.	Break
4:15 p.m.	A Constitutive Model for High Rate Loading and Failure of Composite Materials
4:45 p.m.	Supersonic Particle Deposition
5:15 p.m.	Liquid Resins with Low Styrene Emissions
5:45 p.m.	Discussion/Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Tuesday, May 25

CLOSED SESSION

8:00 a.m.	Panel working breakfast meeting

OPEN SESSION

10:00 a.m.	Wrap-up with senior WMRD management
11:30 a.m.	Adjourn

ARMOR AND ARMAMENTS PANEL
NANOTECHNOLOGY REVIEW TEAM

May 25-27, 2004
Aberdeen Proving Ground, Maryland

Tuesday, May 25

CLOSED SESSION

12:00 p.m. Panel working lunch meeting
1:30 p.m. Travel to Aberdeen Proving Ground (APG)

OPEN SESSION

2:00 p.m. Introduction and Overview of ARL Nanotechnology Program
2:30 p.m. ARO Program in Nanotechnology
3:00 p.m. Nanobioscience and Electronics Technology: ARL and the Institute for Collaborative Biotechnologies (ICB)
3:20 p.m. Break

Nanoelectronics

3:35 p.m. Nanotechnology for Bio Sensors
4:05 p.m. Band-gap Engineering I: Semiconductor Nanostructures for Infrared (IR) Imaging Applications
4:35 p.m. Band-gap Engineering II: Quantum Cascade Laser for IR Countermeasures
5:05 p.m. Nano-Magnetic Resonance Imaging of Electronic and Photonic Materials and Devices
5:35 p.m. Discussion/Adjourn
7:00 p.m. Dinner—panel and ARL staff

Wednesday, May 26

8:00 a.m. Travel to Aberdeen Proving Ground

OPEN SESSION

8:30 a.m. Recap of presentations from May 25
8:50 a.m. Aluminum-Nitride-based Nanoelectromechanical Systems (NEMS) for RF Applications
9:20 a.m. Molecular-Scale Nanodevices
9:50 a.m. Break

Synthesis and Assembly of Nanomaterials Building Blocks

10:05 a.m. Use of Diblock Polymers to Control Surface Nanotopology and Hierarchical Assembly
10:35 a.m. Directed Assembly of Functional Materials
11:05 a.m. Dendritic Surfactants as Vehicles for Directed Assembly
11:35 a.m. Lunch/laboratory tour/poster session

Structural Nanomaterials

1:35 p.m. Induction Processing of Nanomagnetic Particulate Filled Adhesives
2:05 p.m. Development of Rate-Dependent Properties in Polymer Composites Through Fiber Sizing Chemistry
2:35 p.m. Inorganic Nanomaterials
3:05 p.m. Break

Functional Nanomaterials

3:20 p.m. Nanoscale Materials for Fuel Cell and Fuel Processing

High Performance Computing Support for Nanotechnology

3:50 p.m. Computational Nanosciences and Nanomechanics at ARL/Army High Performance Computing Research Center (AHPCRC)
4:20 p.m. Validating Multiscale Methods: High Performance Parallel Ab-Initio Computations of Mechanically-Activated Quantum Processes
4:50 p.m. Discussion/Adjourn

CLOSED SESSION
7:00 p.m. Panel working dinner meeting

Thursday, May 27

CLOSED SESSION
9:00 a.m. Panel working breakfast meeting

OPEN SESSION
1:00 p.m. Wrap-up session with ARL management
2:30 p.m. Adjourn

DIGITIZATION AND COMMUNICATIONS SCIENCE PANEL

April 29-May 1, 2003
Adelphi, Maryland

Tuesday, April 29

OPEN SESSION

5:00 p.m. ARL Overview ("Boot Camp") for new panel members

CLOSED SESSION

6:45 p.m. Panel working dinner meeting

Wednesday, April 30

OPEN SESSION

7:15 a.m. Carpool to Collaborative Technology Alliance (CTA) Conference at University of Maryland University College (UMUC) Conference Center

Attending CTA Conference

8:00 a.m. Call to Order
8:05 a.m. Introductory Remarks
8:10 a.m. Keynote Address
9:00 a.m. Communications and Networks (C&N) CTA Panel Session
10:00 a.m. Break
10:30 a.m. Advanced Decision Architectures (ADA) CTA Panel Session

CISD Presentations

11:35 a.m. Panel convenes in conference room for lunch (with presentations)
11:45 a.m. Welcome
12:00 p.m. Computational and Information Sciences Directorate (CISD) Overview
12:45 p.m. Computer and Communication Sciences Division Overview
1:15 p.m. Intelligent Optics (talk and lab visit)
1:45 p.m. Command and Control in Complex and Urban Terrain
2:15 p.m. Break
2:30 p.m. CTA Conference—Robotics CTA Panel Session
3:45 p.m. Fusion Based Knowledge for the Objective Force
4:15 p.m. Horizontal Fusion—Warrior's Edge
4:45 p.m. Horizontal Fusion—Basic Language Translation Services
5:15 p.m. CTA Conference Exhibits

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Thursday, May 1

7:45 a.m.	Carpool to UMUC Inn and Conference Center

OPEN SESSION

CISD Presentations

(Selected panel members will break out for selected CTA talks as needed)

8:30 a.m.	Assessing the Autonomous Mobility of Robotics: A TRL-6 Experimentation Trilogy
9:00 a.m.	Protection Trade-offs Against Partial-Band and Multiple-Access Interference in Frequency-Hopping Networks
9:30 a.m.	"Org ID Retention" Study
10:00 a.m.	Break
10:15 a.m.	A Scenario-Directed Computational Framework to Aid Decision-Making and Systems Development
10:45 a.m.	High Performance Computing Division Overview
11:15 a.m.	Computational Initiatives Toward Mitigating the Toxic Chemical Environment for the Objective Force
11:45 a.m.	Quantum-Mechanically Accurate Continua: Generating New Material Models for Nanotechnology

CLOSED SESSION

12:15 p.m.	Panel working lunch (in panel meeting room)

OPEN SESSION

2:30 p.m.	Wrap-up question-and-answer session with presenters
3:00 p.m.	Attend CTA Conference concurrent paper sessions
5:15 p.m.	Wrap-up meeting with senior CISD management (in panel meeting room)
6:00 p.m.	Adjourn

DIGITIZATION AND COMMUNICATIONS SCIENCE PANEL
METEOROLOGY SUBGROUP

June 2-4, 2003
Las Cruces and White Sands, New Mexico

Monday, June 2

CLOSED SESSION
7:00 p.m. Panel working dinner meeting

OPEN SESSION
8:30 p.m. Battlefield Environment Division Overview
9:15 p.m. Report on Division-Sponsored Forums
9:30 p.m. Adjourn

Tuesday, June 3
7:15 a.m. Carpool to White Sands Missile Range (WSMR)

OPEN SESSION
8:30 a.m. Atmospheric Effects Overview
9:00 a.m. High-Resolution Modeling of Acoustic Wave Propagation in Atmospheric Environments
9:30 a.m. Modeling and Measurement Research for Aerosol Agent Detection and Characterization
10:00 a.m. Break
10:15 a.m. Target Acquisition Weapons Software (TAWS)
10:45 a.m. Mitigation Atmospheric Effects on IR Imagery
11:15 a.m. Infrasonic Array Technology
11:45 a.m. Set-up for working lunch
12:00 p.m. Environmental Remote Sensing Technology: Laser Intensity Direction and Ranging (LIDAR)

CLOSED SESSION
12:30 p.m. Panel closed meeting

OPEN SESSION
1:00 p.m. Boundary Layer Meteorology Overview
1:20 p.m. Army Nowcasting: Current Weather Forward (CWF)
1:30 p.m. High-Resolution Numerical Simulations over WSMR Using Purdue/National Taiwan University (NTU) Model
2:00 p.m. Coupling Prognostic Numerical Weather Prediction (NWP) Model to Diagnostic Canopy Coupled to Surface Layer Microscale Model
2:30 p.m. Break

2:45 p.m. Development of a Three-Dimensional Diagnostic Wind Model for Complex Terrain/Morphology Using the Multigrid Solution Method
3:15 p.m. Applying a Web-Based Model Evaluation Tool to Mesoscale Model Ensemble Analysis
3:45 p.m. Intercomparison of Turbulent Fluxes from CASES-99 Tower Measurements

CLOSED SESSION

4:15 p.m. Panel closed meeting
5:15 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Wednesday, June 4

OPEN SESSION

8:30 a.m. Atmospheric Investigations and Technology Transitions Overview
9:00 a.m. Overview of IMETS Development Program
9:30 a.m. Master Environmental Library-Environmental Scenario Generator
10:00 a.m. National Polar-orbiting Operational Environmental Satellite System (NPOESS) Interactions
10:30 a.m. ARL Participation in Joint Urban 2003
10:45 a.m. Remote Data Collection and Transfer Techniques

CLOSED SESSION

11:15 a.m. Panel working lunch meeting

OPEN SESSION

12:45 p.m. Wrap-up session with entire group
1:00 p.m. Adjourn

DIGITIZATION AND COMMUNICATIONS SCIENCE PANEL

May 10-12, 2004
Adelphi, Maryland

Monday, May 10

CLOSED SESSION

7:00 a.m.	Panel working breakfast meeting

OPEN SESSION

8:30 a.m.	Panel carpools to ARL
9:30 a.m.	Welcome
9:45 a.m.	Computational and Information Sciences Directorate (CISD) Overview
10:25 a.m.	Horizontal Fusion Support to Actionable Intelligence
10:55 a.m.	Break
11:10 a.m.	Computer and Communication Sciences Division Overview
11:35 a.m.	Command and Control in Complex and Urban Terrain
12:00 p.m.	Lunch
12:45 p.m.	Basic Language Translation Services
1:15 p.m.	Integrated Autonomous Assets for the Warrior
1:40 p.m.	Sensor Fusion for Counter Mortar
2:05 p.m.	Data Mining Combat Simulations
2:30 p.m.	Break
2:45 p.m.	Fusion Based Knowledge for the Future Force
3:10 p.m.	Survivable Communications—Assistant Secretary of the Army-Acquisition, Logistics and Technology (ASAALT) 6.1 Review
3:35 p.m.	Sensor Radio Development

CLOSED SESSION

4:00 p.m.	Panel closed session

OPEN SESSION

4:30 p.m.	Question-and-answer session with all CISD presenters
5:00 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner

Tuesday, May 11

OPEN SESSION

7:15 a.m.	Carpool to ARL
8:00 a.m.	Breakfast with CISD staff

8:30 a.m.	Intelligent Optics—ASAALT 6.1 Review
8:55 a.m.	Target-in-the-Loop Beam Control
9:45 a.m.	Break
10:00 a.m.	Battlefield Environment Division Overview
10:25 a.m.	Joint Urban 2003 Atmospheric Boundary Layer Field Experiment
10:50 a.m.	Rapid Aerosol Agent Detector
11:15 a.m.	High-Resolution Meteorological Nowcasting System
11:40 a.m.	Lunch
12:30 p.m.	Dispersion Assessment Tool
12:55 p.m.	Atmospheric Effects—ASAALT 6.1 Review
1:20 p.m.	High Performance Computing Division Overview
1:45 p.m.	AHPCRC—ASAALT 6.1 Review
2:10 p.m.	Break
2:25 p.m.	MINDS: Data Mining Based Network Intrusion Detection System
2:50 p.m.	High Performance Computing (HPC) Modeling of Adsorption and Decomposition of the Nerve Agents

CLOSED SESSION

3:25 p.m. Panel closed meeting

OPEN SESSION

4:00 p.m. Question-and-answer session with all CISD presenters
4:45 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Panel working dinner

Wednesday, May 12

CLOSED SESSION

7:30 a.m. Panel working breakfast and consensus session

OPEN SESSION

9:30 a.m. Wrap-up session with senior CISD management

CLOSED SESSION

11:00 a.m. Panel writing session
12:00 p.m. Adjourn

DIGITIZATION AND COMMUNICATIONS SCIENCE PANEL
ROBOTICS REVIEW TEAM

May 13-15, 2004
Carlisle, Maryland

Thursday, May 13

7:30 a.m.	Panel travels to Army War College

CLOSED SESSION

8:00 a.m.	Panel closed meeting

OPEN SESSION

Technology Demonstrations

9:30 a.m.	Travel to ARL Robotics Facility (Fort Indiantown Gap, Pa.)
10:30 a.m.	Robotics demonstrations at ARL Robotics Facility
12:30 p.m.	Return to Army War College
1:30 p.m.	Tour exhibits at Army War College's "Robotic Day" event

Program Overview

3:00 p.m.	ARL Robotics Overview

Research in Perception

4:00 p.m.	Collaborative Technology Alliance (CTA) Perception Research
6:00 p.m.	No-host dinner

Friday, May 14

OPEN SESSION

9:00 a.m.	Ultrawideband (UWB) Radar for Autonomous Mobility
9:30 a.m.	Hyperspectral Sensing for Autonomous Mobility
10:00 a.m.	Ladar for Small Robots
10:30 a.m.	Stereo Perception
10:50 a.m.	Break

Research in Intelligent Control

11:00 a.m.	Robotics CTA Intelligent Control Research

11:30 a.m.	Four-Dimensional Real-time Control System (4D/RCS) Control Architecture and Tactical Behaviors
12:00 p.m.	Lunch
1:00 p.m.	Tactical Behaviors for Unmanned Air Vehicles and Unmanned Ground Vehicles
1:30 p.m.	ARO Intelligent Control Programs

Research in Human-Robot Interfaces

2:15 p.m.	Robotics CTA Human-Robot Interface Research
2:45 p.m.	Human-Robot Interface for Robotic Teaming STO
3:15 p.m.	Break
3:30 p.m.	Advanced Decision Architecture CTA Robotics Research
4:00 p.m.	Modeling Robot Soldier Teams for Multitasking Mounted and Dismounted Missions

Research Pertaining to Mission Packages

4:30 p.m.	Warrior's Edge
5:10 p.m.	SOAR
5:30 p.m.	Conclusion

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Saturday, May 15

CLOSED SESSION

9:00 a.m.	Panel closed meeting

OPEN SESSION

12:00 p.m.	Review team meets with ARL directors for clarification session
1:30 p.m.	Adjourn

SENSORS AND ELECTRON DEVICES PANEL

April 6-9, 2003
Adelphi, Maryland

Sunday, April 6

OPEN SESSION

6:30 p.m.	Panel working dinner and Sensors and Electron Devices Directorate (SEDD) orientation for new panel members

Monday, April 7

CLOSED SESSION

7:45 a.m.	Panel working breakfast meeting

OPEN SESSION

8:45 a.m.	Carpool to Army Research Laboratory
9:30 a.m.	Welcome
9:45 a.m.	SEDD Overview

Power and Energy

10:30 a.m.	Power and Energy Thrust Overview
11:00 a.m.	Break
11:15 a.m.	Power and Energy Collaborative Technology Alliance (CTA) Overview
11:45 a.m.	SiC Devices Power and Energy CTA (PE-CTA)
12:10 p.m.	Lunch
12:45 p.m.	SiC Devices
1:10 p.m.	Logistics Fuel Reformation (PE-CTA)
1:35 p.m.	Logistics Fuel Reformation
2:05 p.m.	Advanced Sensors CTA Overview
2:30 p.m.	Electro-Optic Smart Sensors Thrust Overview
2:55 p.m.	III-V IR Detector Alternatives for Thermal Imaging
3:20 p.m.	Break
3:30 p.m.	Antimonide Superlattice IR Detectors Advanced Sensors CTA (AS-CTA)
3:55 p.m.	Interband Cascade Lasers for IR Countermeasures
4:20 p.m.	Photoacoustic Detection of Chemical Vapors
4:35 p.m.	Bioelectronic Detection of Hazardous Materials
4:50 p.m.	Opto-electronic Sensor/Eye Protection
5:15 p.m.	Quantum Cryptography (laboratory tour)
5:40 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Tuesday, April 8

OPEN SESSION

7:15 a.m.	Carpool to Army Research Laboratory
8:00 a.m.	Breakfast with SEDD scientific staff

Autonomous Sensing Thrust

8:30 a.m.	Autonomous Sensing Overview
8:50 a.m.	Acoustic Overview
9:05 a.m.	Acoustic Localization
9:30 a.m.	Localization/Orientation (AS-CTA)
9:50 a.m.	Infrasound Research
10:15 a.m.	Break
10:30 a.m.	Image Processing Overview
10:45 a.m.	Higher Order Zero Crossings/Semiparametric Approach for Automatic Target Detection (ATD)
11:10 a.m.	Anomaly Detection for Hyperspectral Images
11:35 a.m.	Target Detection for Forward Looking Infrared (FLIR) Imagery
12:00 p.m.	“Skip-level” lunch with scientists and engineers

Multifunction RF (MFRF) Technology

1:00 p.m.	Multifunction RF Technology Overview
1:10 p.m.	Defense Advanced Research Projects Agency (DARPA) Tri-Service Wideband Gap Electronics
1:25 p.m.	GaN—RF Components (AS-CTA)
1:55 p.m.	Metamorphic High Electron Mobility Transistors (MHEMT) Microwave and Millimeter Integrated Circuits (MMICs) for MFRF (AS-CTA)
2:20 p.m.	MFRF Front-End Technology
2:50 p.m.	Break
3:10 p.m.	Countermine
3:35 p.m.	Active Protection
4:00 p.m.	Ferroelectrics

CLOSED SESSION

4:25 p.m.	Closed panel session

OPEN SESSION

4:55 p.m.	Wrap-up question-and-answer session with all SEDD presenters
5:25 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner

Wednesday, April 9

CLOSED SESSION

8:00 a.m. Panel working breakfast meeting

OPEN SESSION

10:30 a.m. Wrap-up meeting with senior SEDD management
11:30 a.m. Panel discussion with SEDD director
12:00 p.m. Adjourn

SENSORS AND ELECTRON DEVICES PANEL

April 26-28, 2004
Adelphi, Maryland

Monday, April 26

CLOSED SESSION

7:00 a.m. Panel working breakfast meeting

OPEN SESSION

8:30 a.m. Carpool to Army Research Laboratory
9:00 a.m. Welcome
9:15 a.m. Sensors and Electron Devices Directorate (SEDD) Overview

Directed Energy and Power Generation

9:45 a.m. Power and Energy Thrust Overview
10:00 a.m. High Power Li-Ion Batteries—Recent Advances in Electrolyte and Electrode Materials
10:20 a.m. Advanced Primary Lithium Batteries
10:40 a.m. Break
10:55 a.m. Fuel Cells for the Army
11:15 a.m. Power and Energy CTA Overview
11:30 a.m. A Three-Phase Utility Power Supply Based on the Matrix Converter
11:50 a.m. Lunch
12:50 p.m. Development of Gate Oxides for SiC Metal Oxide Semiconductor (MOS)
1:10 p.m. Identification of SiC/SiO_2 Interface and Near-Interface Traps in SiC MOS via Electron Spin Resonance

Signal and Image Processing

1:30 p.m. Autonomous Sensing Overview
1:45 p.m. Acoustic Overview
2:00 p.m. Acoustic Impulse Localization
2:15 p.m. Acoustic Microsensors and Sensor Fusion
2:35 p.m. Break
2:50 p.m. Hyperspectral Anomaly Detection
3:15 p.m. Disposable Sensing
3:30 p.m. Magnetic Sensing

Technology Exposition—Signal and Image Processing (SIP) Display Laboratory

3:55 p.m. Demo/Display on topics directly related to ongoing operations (microsensors)
1. Infrasonic Arrays
2. Acoustic Database
3. Sniper/Mortar Detection
4. Humvee Gun Mount

5:00 p.m. Wrap-up

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Tuesday, April 27

OPEN SESSION

7:15 a.m. Panel leaves hotel for ARL
8:00 a.m. Breakfast and interaction on basic R&D with SEDD staff
9:15 a.m. Fusion of Acoustic and Imaging Sensing

RF and Electronics

9:45 a.m. Multifunction Radio-Frequency (MFRF) Thrust Overview
10:00 a.m. Multifunction RF
10:30 a.m. High-Frequency Electronics: RF and Mixed Signal
11:00 a.m. Break
11:15 a.m. Piezoelectric MEMS and Nanodevice Research: Design, Modeling, Prototype, and Testing
11:45 a.m. Booby Trap Detection
12:15 p.m. Lunch

Electro-Optics and Photonics

1:30 p.m. Electro-Optics Thrust Overview
1:45 p.m. Environmental Sensing
2:15 p.m. Cold Atom Optics Research
2:35 p.m. Advanced Sensors CTA Overview
2:50 p.m. Break
3:05 p.m. Type II Superlattices for Infrared Detector Applications
3:35 p.m. Development of InGaAs-Based Metal-Semiconductor-Metal Optoelectronic Mixers for Chirped Amplitude-Modulated Laser Radar

CLOSED SESSION

4:00 p.m. Closed panel session

OPEN SESSION

4:30 p.m. Wrap-up question-and-answer session with all SEDD presenters
5:00 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Wednesday, April 28

CLOSED SESSION

8:00 a.m. Panel working breakfast and consensus session

OPEN SESSION

10:30 a.m. Wrap-up session with senior SEDD management

12:00 p.m. Adjourn

SOLDIER SYSTEMS PANEL

June 10-12, 2003
Fort Sill, Oklahoma

Tuesday, June 10

CLOSED SESSION

8:30 a.m.	Panel in closed session

OPEN SESSION

9:30 a.m.	Travel to ARL's Human Research and Engineering Directorate (HRED)
10:00 a.m.	Welcome and Overview
11:00 a.m.	Depth and Simultaneous Battlelab Overview
12:00 p.m.	Working lunch
12:20 p.m.	Support to the U.S. Army Medical Department (AMEDD)
12:40 p.m.	Advanced Decision Architectures Collaborative Technology Alliance (CTA) Overview
1:10 p.m.	Group 1—Advanced Decision Architectures CTA: Situation Awareness in the Army Objective Force
	Group 2—Advanced Decision Architectures CTA: Dimensions of Human Agent Coordination
2:05 p.m.	Group 1—Advanced Decision Architectures CTA: Dimensions of Human Agent Coordination
	Group 2—Advanced Decision Architectures CTA: Situation Awareness in the Army Objective Force
2:55 p.m.	Break
3:05 p.m.	JANUS Facility Overview and Tour
	Soldier Systems Panel
	All others
3:45 p.m.	Group 1—Cognitive Foundation of Performance in Military Environments: Cognitive Readiness Research to Support Army Transformation
	Group 2—Auditory Awareness and Speech Communications: Bone Conduction
4:15 p.m.	Group 1—Auditory Awareness and Speech Communications: Bone Conduction
	Group 2—Cognitive Foundation of Performance in Military Environments: Cognitive Readiness Research to Support Army Transformation
4:45 p.m.	Adjourn
6:30 p.m.	Dinner—Panel and ARL/HRED staff

Wednesday, June 11

OPEN SESSION

7:30 a.m.	Travel to ARL/HRED
8:00 a.m.	Group 1—FCS Human Factors Program Architecture
	Group 2—Soldier Research in Information Systems: Adaptability in Coalition Teamwork

8:55 a.m.	Group 1—Soldier Research in Information Systems: Adaptability in Coalition Teamwork
	Group 2—FCS Human Factors Program Architecture
9:55 a.m.	Group 1— Human Factors Engineering (HFE) and Manpower and Personnel Integration (MANPRINT) Support to Maneuver and Mobility Systems: Fixed Bridge Construction
	Group 2—HFE and MANPRINT Support to Weapons Systems: LW155 Howitzer
10:30 a.m.	Group 1—HFE and MANPRINT Support to Weapons Systems: LW155 Howitzer
	Group 2—HFE and MANPRINT Support to Maneuver and Mobility Systems: Fixed Bridge Construction
11:10 a.m.	Group 1—Soldier-Centered Analysis for the Objective Force: Unit of Action Analyses
	Group 2—HFE and MANPRINT Support to Weapons Systems: Ground-Based Mid-Course Defense
12:00 p.m.	Working lunch
12:20 p.m.	Proposed STO: Technology for Human Robotic Interaction in Soldier Robot Teaming
12:50 p.m.	Group 1—HFE and MANPRINT Support to Weapons Systems: Ground-Based Mid-Course Defense
	Group 2—Soldier-Centered Analysis for the Objective Force: Unit of Action Analyses

CLOSED SESSION

1:45 p.m.	Panel in closed session
5:00 p.m.	Adjourn

Thursday, June 12

CLOSED SESSION

8:00 a.m.	Panel in closed session

OPEN SESSION

10:30 a.m.	Panel meets with HRED scientists
11:30 a.m.	Panel meets with HRED management
12:00 p.m.	Adjourn

SOLDIER SYSTEMS PANEL

April 14-16, 2004
Aberdeen Proving Ground, Maryland

Wednesday, April 14

CLOSED SESSION

8:00 a.m.	Panel in closed session

OPEN SESSION

9:30 a.m.	Travel to ARL/HRED
10:00 a.m.	Welcome and Overview
11:10 a.m.	Group 1—Cognitive Foundation of Performance in Military Environments Group 2—Situational Understanding as an Enabler for Unit of Action (UoA) Maneuver Team Soldiers; Cognitive Foundation of Performance in Military Environments
12:00 p.m.	Lunch
12:55 p.m.	Group 1—Situational Understanding as an Enabler for UoA Maneuver Team Soldiers; Cognitive Foundation of Performance in Military Environments Group 2—Cognitive Foundation of Performance in Military Environments
1:50 p.m.	Groups 1 and 2—travel to Building 518
1:55 p.m.	Groups 1 and 2—Tactical Environment Simulation Facility
2:05 p.m.	Groups 1 and 2—travel to Building 520
2:10 p.m.	Group 1—Visual Perception and Sensory Modeling Group 2—Auditory Research Tour
3:00 p.m.	Groups 1 and 2—break
3:10 p.m.	Group 1—Auditory Research Tour Group 2—Visual Perception and Sensory Modeling
4:00 p.m.	Groups 1 and 2—en route
4:05 p.m.	Group 1—Crew Integration and Automated Testbed; High-Fidelity Ground Platform and Terrain Mechanics Group 2—HFE and MANPRINT Support to Maneuver and Mobility Systems
4:55 p.m.	Adjourn
6:30 p.m.	Dinner—Panel and ARL/HRED staff

Thursday, April 15

OPEN SESSION

7:30 a.m.	Travel to ARL/HRED
8:00 a.m.	Group 1—HFE and MANPRINT Support to Maneuver and Mobility Systems Group 2—Crew Integration and Automated Testbed; High-Fidelity Ground Platform and Terrain Mechanics

9:00 a.m.	Group 1—Situational Understanding as an Enabler for UoA Maneuver Team Soldiers Group 2—Human Performance Research for Future Warrior Systems; Command and Control (C2) in Complex and Urban Terrain
9:50 a.m.	Groups 1 and 2—break and travel
10:05 a.m.	Group 1—Human Performance Research for Future Warrior Systems; C2 in Complex and Urban Terrain Group 2—Situational Understanding as an Enabler for UoA Maneuver Team Soldiers
11:00 a.m.	Groups 1 and 2—MANPRINT Modeling; Human Systems Integration Modeling
12:00 p.m.	Lunch and general discussion

CLOSED SESSION

12:45 p.m.	Panel in closed session
5:00 p.m.	Adjourn

Friday, April 16

CLOSED SESSION

8:00 a.m.	Panel in closed session

OPEN SESSION

10:30 a.m.	Panel meets with HRED scientists
11:30 a.m.	Panel meets with HRED management
12:00 p.m.	Adjourn

SURVIVABILITY AND LETHALITY ANALYSIS PANEL

May 27-30, 2003
Las Cruces/White Sands, New Mexico

Tuesday, May 27

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Wednesday, May 28

CLOSED SESSION

7:00 a.m.	Panel working breakfast meeting
8:15 a.m.	Carpool to White Sands Missile Range

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

9:30 a.m.	Administrative/Security Briefing
9:35 a.m.	Welcome

Overviews

9:45 a.m.	ARL Overview
10:15 a.m.	Survivability and Lethality Analysis Directorate (SLAD) “Boot Camp”/Overview
10:45 a.m.	Air and Missile Defense (AMD) Overview
11:00 a.m.	Missile Defense Agency (MDA) Black Team Initiatives
11:20 a.m.	Command, Control, Communications, Computers, and Intelligence (C4I) Overview
11:40 a.m.	Break
12:00 p.m.	Aviation Systems Overview
12:20 p.m.	Munitions Overview
12:30 p.m.	Ground Systems Overview
12:45 p.m.	Future Combat System (FCS) Overview
12:45 p.m.	Lunch

Decision-Related Structures

1:15 p.m.	Motivation for Decision-Related Structures (DRS) Program
1:35 p.m.	DRS Introduction and Framework
2:15 p.m.	Milestone I Results
3:00 p.m.	Break
3:30 p.m.	Analysis Tools: Formal Concept Analysis
4:15 p.m.	Milestone II
5:00 p.m.	Adjourn

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Thursday, May 29

7:00 a.m. Carpool to White Sands Missile Range

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

8:15 a.m. Breakfast with SLAD scientific staff

Information Operations (IO)/Command, Control, Communications, Computers, and Intelligence (C4I)

8:45 a.m. Recent Central Test Support Facility (CTSF) and Foundations Product Investigations
9:45 a.m. Situational Awareness Network Traffic Analysis
10:45 a.m. Break
10:55 a.m. IO Experimental Capability
FCS Demonstration Activities
11:25 a.m. Warfighter Information Network-Tactical (WIN-T) Program Support
11:55 a.m. Recent Investigations of Joint Tactical Radio System (JTRS)
12:30 p.m. "Skip-level" lunch with scientists and engineers

Parallel Session 1: Infrared (IR)/Electro-Optics (EO)

1:30 p.m. IR Signature Measurements
2:30 p.m. M1A2 Systems Enhancement Package (SEP) Activities
3:00 p.m. Break
3:20 p.m. IR Modeling
3:40 p.m. Infrared HardWare in the Loop (IRHWIL) and Man-Portable Air Defense Systems (MANPADS)

Parallel Session 2: Radio Frequency (RF)

1:30 p.m. Advanced Countermeasures (CM) Program Activities
RF Tools, Techniques, and Methodologies (TTM) Activities
2:15 p.m. Methodologies
2:40 p.m. RFCM Modeling
3:00 p.m. Break
3:20 p.m. Radar Waveform Distortion Analysis
3:45 p.m. Radar Target/Jammer Simulator (RTJS)
4:10 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Friday, May 30

CLOSED SESSION

8:00 a.m. Panel working breakfast meeting

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

10:30 a.m. Wrap-up meeting with senior SLAD management

12:00 p.m. Adjourn

SURVIVABILITY AND LETHALITY ANALYSIS PANEL

May 3-5, 2004
Aberdeen Proving Ground, Maryland

Monday, May 3

CLOSED SESSION

7:30 a.m.	Panel working breakfast meeting
8:45 a.m.	Departure from hotel to Aberdeen Proving Ground (APG)

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

9:30 a.m.	Welcome
9:45 a.m.	SLAD Overview and Strategic Plan
10:30 a.m.	Missions and Means Framework
11:45 a.m.	System of Systems Survivability Simulation (S4) Overview
12:15 p.m.	Lunch
1:15 p.m.	Network Modeling and Assessment Overview
2:00 p.m.	Ballistics and Nuclear, Biological, and Chemical (NBC) Division Overview
2:30 p.m.	Break
2:45 p.m.	MUVES 3 Project Overview and Software Status
3:25 p.m.	MUVES 3 Methodology Review Board
3:55 p.m.	MUVES 3 Architecture
4:25 p.m.	BRL-CAD Geometry Considerations and Improvement Options
4:55 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner meeting

Tuesday, May 4

7:45 a.m.	Departure from hotel to APG

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

8:30 a.m.	Target Interaction Lethality Vulnerability (TILV) Overview and Transitions
9:00 a.m.	TILV: Blast and Shock Program
9:30 a.m.	TILV: Active Protection Systems (APS) Program
10:00 a.m.	Break
10:15 a.m.	Data Management Initiatives
10:45 a.m.	Military Operations on Urban Terrain (MOUT): Buildings and Bunkers, Initiatives, and Collaborations
11:15 a.m.	NBC Program Focus Areas
11:45 a.m.	Lunch with SLAD personnel
12:45 p.m.	Operation Iraqi Freedom (OIF) Support Initiatives

1:15 p.m. Future Combat Systems (FCS) Program Overview
1:45 p.m. Marine Corps Support: Expeditionary Fighting Vehicle (EFV)
2:15 p.m. Break
2:30 p.m. Aircraft Program Support: Kiowa, Comanche

CLOSED SESSION

3:15 p.m. Panel deliberations in closed session

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

3:45 p.m. Wrap-up question-and-answer session with all SLAD presenters
4:30 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Panel working dinner meeting

Wednesday, May 5

CLOSED SESSION

8:00 a.m. Panel working breakfast and consensus session

DATA-GATHERING SESSION NOT OPEN TO THE PUBLIC

10:30 a.m. Wrap-up question-and-answer session with senior SLAD management
12:00 p.m. Adjourn

Appendix D

Assessment Criteria

2004 ASSESSMENT CRITERIA

1. Effectiveness of Interaction with the Scientific and Technical Community:
    a. Papers in quality refereed journals and conference proceedings (and their citation index)
    b. Presentations and colloquia
    c. Participation in professional activities (society officers, conference committees, journal editors)
    d. Educational outreach (serving on graduate committees, teaching/lecturing, invited talks, mentoring students)
    e. Fellowships and awards (external and internal)
    f. Review panel participation (Army Research Office (ARO), National Science Foundation (NSF), Multidisciplinary University Research Initiative (MURI), …)
    g. Recruiting new talent into the Army Research Laboratory (ARL)
    h. Patents and Intellectual Property (IP) (and examples of how the patent or IP is used)
    i. Involvement in building an ARL-wide cross-directorate community
    j. Public recognition, e.g., in the press and elsewhere, for ARL research

2. Impact on Customers:
    a. Documented transfer/transition of technology, concepts or program assistance from ARL to Research, Development, and Engineering Centers (RDECs) or RDEC contractors for both the long term and short term
    b. Direct funding from customers to support ARL activities
    c. Documented demand for ARL support or services (is there competition for their support?)
    d. Customer involvement in directorate planning

e. Participation in multidisciplinary, cross-directorate projects
f. Surveys of customer base (direct information from customers on value of ARL research)

3. Formulation of Projects' Goals and Plan
   a. Is there a clear tie to ARL Strategic Focus Areas, Strategic Plan, or other ARL need?
   b. Are tasks well defined to achieve objectives?
   c. Does the project plan clearly identify dependencies (i.e., successes depend on success of other activities within the project or outside developments)?
   d. If the project is part of a wider activity, is role of the investigators clear, and are the project tasks and objectives clearly linked to those of other related projects?
   e. Are milestones identified, if they are appropriate? Do they appear feasible?
   f. Are obstacles and challenges defined (technical, resources)?
   g. Does the project represent an area where application of ARL strengths is appropriate?

4. R&D Methodology
   a. Are the hypotheses appropriately framed within the literature and theoretical context?
   b. Is there a clearly identified and appropriate process for performing required analyses, prototypes, models, simulations, tests, and so on?
   c. Are the methods (e.g., laboratory experiment, modeling/simulation, field test, analysis) appropriate to the problems? Do these methods integrate?
   d. Is the choice of equipment/apparatus appropriate?
   e. Is the data collection and analysis methodology appropriate?
   f. Are conclusions supported by the results?
   g. Are proposed ideas for further study reasonable?
   h. Do the trade-offs between risk and potential gain appear reasonable?
   i. If the project demands technological or technical innovation, is that occurring?
   j. What stopping rules, if any, are being or should be applied?

5. Capabilities and Resources
   a. Are the qualifications and number of the staff (scientific, technical, administrative) appropriate to achieve success of the project?
   b. Is funding adequate to achieve success of the project?
   c. Is the state of the equipment and facilities adequate?
   d. If staff, funding, or equipment are not adequate, how might the project be triaged (what thrust should be emphasized, what sacrificed?) to best move toward its stated objectives?
   e. Does the laboratory sustain the technical capability to respond quickly to critical issues as they arise?

6. Responsiveness to the Board's Recommendations
   a. Have the issues and recommendations presented in the previous report been addressed?

Appendix E

Selected Acronyms

APG	Aberdeen Proving Ground
ARL	Army Research Laboratory
ARLTAB	Army Research Laboratory Technical Assessment Board
ARO	Army Research Office
ARV	Armed Robotic Vehicle
ASCED	Active Stall Control Engine Demonstration
BED	Battlefield Environment Division
BLTS	basic language translation services
BST	barium-strontium titanate
C2CUT	Command and Control in Complex and Urban Terrains
CE	chemical energy
CISD	Computational and Information Sciences Directorate
CMC	ceramic matrix composite
COTS	commercial off-the-shelf
CRADA	Cooperative Research and Development Agreement
CTA	Collaborative Technology Alliance
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DOE	Department of Energy
DRS	Decision Related Structures (software)

EW	electronic warfare
4D/RCS	Four-Dimensional Real-time Control System
FCS	Future Combat System
FEM/FEA	finite elements method/finite elements analysis
GEAE	General Electric Aircraft Engines
GOTS	government off-the-shelf
HF	Horizontal Fusion
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HRED	Human Research and Engineering Directorate
HRI	human-robot interface
ICB	Institute for Collaborative Biotechnologies
IED	improvised explosive device
IEEE	Institute of Electrical and Electronics Engineers
IEW	Intelligence and Electronic Warfare (software)
IMETS	Integrated Meteorological System (software)
IMPRINT	Improved Performance Research Integration Tool (software)
IO	information operations
ISN	Institute for Soldier Nanotechnologies
IW	information warfare
KE	kinetic energy
LADAR	laser detection and ranging
MANPRINT	Manpower and Personnel Integration (program)
MEMS	microelectromechanical systems
MMF	Mission and Means Framework (software)
MPT	manpower, personnel, and training
MRI	magnetic resonance imaging
MULE	Multifunction Utility/Logistics Equipment
MURI	Multidisciplinary University Research Initiative
MUVES	Modular UNIX-based Vulnerability Estimation Suite (software)
NAE	National Academy of Engineering
NASA	National Aeronautics and Space Administration
NBC	nuclear, biological, and chemical
NNI	National Nanotechnology Initiative
NRC	National Research Council
OCU	Operator Control Unit
PDA	personal digital assistant

PEM FC	polymer electrolyte membrane fuel cell
PEO	program executive officer
PM	program manager
R&D	research and development
RDEC	Research, Development, and Engineering Center
RF	radio frequency
S4	Systems of Systems Survivability Simulation (software)
S&Es	scientists and engineers
SARAP	Survivable, Affordable, Reparable Airframe Program
SBIR	Small Business Innovation Research
SEDD	Sensors and Electron Devices Directorate
SIPRnet	Secret Internet Protocol Router Network
SLAD	Survivability and Lethality Analysis Directorate
SLV	survivability, lethality, and vulnerability
SUGV	Soldier Unmanned Ground Vehicle
TARDEC	Tank-Automotive Research, Development, and Engineering Center
TILV	Target Interaction Lethality Vulnerability (software)
TPA	Technology Planning Annex
TRADOC	Training and Doctrine Command
UEET	Ultra Efficient Engine Technology
UML	unified modeling language
VTD	Vehicle Technology Directorate
WMRD	Weapons and Materials Research Directorate
XUV	Experimental Unmanned Vehicle