2001-2002 Assessment of the Army Research Laboratory

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the 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:

Howard R. Baum, National Institute of Standards and Technology,
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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.

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Introduction

The Army Research Laboratory (ARL) Technical Assessment Board ("the Board") consists of 12 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, six of them as panel chairs. The panels range in size from 10 to 14 members whose expertise is tailored to the technical fields covered by the directorate(s) that they review. In total, 58 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 balanced slates of experts without conflicts of interest and with balanced perspectives. The 58 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. Thirteen 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). Biographical information on the Board and panel members, along with a chart listing the Board and panel membership and each panel's counterpart organization within ARL, appears in Appendix B.

The Board's charge is to provide biennial assessments of the scientific and technical quality of ARL, including findings and recommendations related to the quality and appropriateness of the R&D for each of ARL's technical areas. The Board is to provide peer assessments of the quality of the scientific and

[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 also tabulates 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 assess how well ARO and ARL's in-house research and development are coordinated.

engineering R&D at ARL, not to focus on programmatic advice. Because these assessments are commissioned by ARL rather than by one of ARL's parent organizations, this report has a collegial, rather than a prescriptive, tone. That is, the Board assumes that ARL is receptive to its advice, and accordingly it focuses more on suggestions for improvement rather than on hard-and-fast recommendations.

The current report is the second biennial report of the Board. The first biennial report appeared in 2000, and annual reviews by the Board appeared in 1996, 1997, and 1998. Like the earlier reviews, this report contains the Board's judgments about the quality of ARL's work. 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 peer review of ARL is based on a large amount of information from and on interactions with ARL staff. Most of the information exchange occurs during annual meetings convened by each panel at the appropriate ARL sites. The level of exchange and acceptance of external comments have reached a very healthy level at ARL. The assessment panels engaged in many constructive and collegial interactions at their 2001 and 2002 site visits. In addition, useful 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 information sources.

Agendas for the 2001 and 2002 meetings of the panels are presented in Appendix C. The assessment criteria applied (weighted in a way appropriate to the work under review) to each technical project are contained in Appendix D. Because they focus on providing expert reviews, the panels do not weigh in on performance indicators (e.g., publication counts, conference attendance) that are tracked internally by ARL. Panel meetings last 2 or $2^1/_2$ days, during which time the panel members receive a combination of overview and technical briefings. (Some panels receive extensive read-ahead materials, including staff publications.) The overview briefings by ARL management bring the panels up to date on the Army's long-range planning, a context-building step that is needed because the panels purposely consist mostly of people who are not engaged in work focused on Army matters. Ample time is devoted to discussion, both to clarify a panel's understanding and to convey the observations and suggestions of individual panel members to ARL's scientists and engineers (S&Es). Important issues or gaps in a panel's understanding are discussed after the meeting so that the panel is confident of the accuracy and completeness of its assessments. When necessary, the panels receive presentations that are classified at the Department of Defense (DOD) "Secret" level.

In addition to the insights gained from the panel meetings, Board members receive additional 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) each year, at which those directorates discuss their programs with the directorates' customers. One Board member attended the 2002 symposium that launched ARL's new Collaborative Technology Alliances (CTAs). It is expected that many more Board and panel members will attend future meetings of the CTAs. In addition, two members of the Digitization and Communications Science Panel participated in an August 2002 workshop organized by ARL's Computational and Information Sciences Directorate (CISD) as input into that unit's future directions in meteorology. The Board and its panels are supported by National Research Council (NRC) staff, who interact with ARL on an ongoing 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 4 years, staggered so that there is regular turnover and a refreshing of viewpoints.

In July 2002, the Board met for 2 days to share members' summaries of their panels' observations and concerns; this report represents the 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 2001-2002 period and distilled from them a short list of the main trends, opportunities, and challenges that merit attention at the level of the ARL Director. Specific ARL projects are used to illustrate these points 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.

2

Changes Since the 1999-2000 Assessment

Overall, the Technical Assessment Board (TAB) continues to see improvements across ARL and is pleased with the level of ARL responsiveness to its outside assessments. There are cases, discussed in this chapter, in which ARL has taken steps to respond to concerns expressed and recommendations made in the Board's 1999-2000 report and to comments offered at the 2001 and 2002 panel meetings. However, in other cases, also discussed in this chapter, ARL scientists and engineers have not acted on information or suggestions from panel meetings in 2000 or 2001. The Board understands that a group that visits a laboratory for a relatively brief period each year has only a partial understanding of the factors that influence or limit the laboratory's program, and so it may make some recommendations that are not feasible or optimal. The Board and its panels are working jointly with ARL to improve the feedback loop so that the panels receive annual updates on actions in response to, or regarding rejections of, their various recommendations.

For the convenience of the reader, the major recommendations from the Board's 1999-2000 report[1] follow:

> ARL needs to have an appropriate balance of long-range and applied work and enough ARL-directed funding to allow it to follow through on critical topics that might otherwise not be investigated.
>
> ARL S&Es should be encouraged to interact with S&Es doing related work anywhere, whether in their own unit of ARL, in other units of ARL, or outside ARL. The Board has observed the potential value of increased coordination and collaboration between WMRD and SLAD, between SLAD and HRED, and between SEDD and CISD, to name a few internal opportunities.
>
> Real bilateral value could be gained from increasing the synergy between the R&D and analysis arms of ARL units. The possibility for such synergy is seriously limited by current funding and workload constraints.
>
> ARL's strong and/or unique capabilities (e.g., the Zahl Physical Sciences Laboratory and the Major Shared Resource Center at Aberdeen) could be further exploited or profitably expanded to the benefit of the organization itself, the Army as a whole, and in some cases to the technical community at large. Some instrumentation at ARL's White Sands facility needs to be upgraded.

[1]National Research Council (NRC). 2000. *1999-2000 Assessment of the Army Research Laboratory*. National Academy Press, Washington, D.C. (hereafter cited as NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory*).

ARL could take greater advantage of its world-class experience, skills, or accomplishments in engine stall/surge control and millimeter-wave technology.

There is a great need to understand the vulnerabilities of the digital Army, and ARL must develop this capability.

Throughout ARL there is a need to address staffing, including both the hiring of new people and the replacement of departing experts.

ARL should ensure that models, simulations, and computer codes are being evaluated to define their scope of applicability and that they are updated, validated, and revised in order to provide the most reliable and timely answers to practical questions.

RESPONSIVENESS TO PARTICULAR RECOMMENDATIONS IN THE 1999-2000 REPORT

Improvements Made to Some Outdated Instrumentation at ARL's White Sands Site

The Board's 1999-2000 report raised some concern that the effectiveness and efficiency of the Survivability and Lethality Analysis Directorate (SLAD) were being impeded by outdated instrumentation at its site in White Sands, New Mexico. At that time, the Board heard about two instances in which staff had to make do with instrumentation that was barely adequate: the needed data could be collected only through the ARL investigators' extra efforts, ingenuity, and persistence. Shortly after that report appeared, ARL provided SLAD with additional funds for equipment, and the problem has apparently been addressed. The Board's panel for SLAD will revisit the White Sands facility in 2003, at which time it will be able to assess the degree of progress.

New Program Begun for Rotorcraft Engine Surge Control

Another notable update is ARL's response to the 1999-2000 recommendation for a program in engine stall/surge control. That report noted as follows:

> Helicopter operation in regions with airborne particulates (such as might be encountered over unimproved runways, in desert regions, or in combat zones) 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 forms of engine deterioration degrade performance (efficiency) and surge margin. The loss of engine performance is undesirable because it reduces the load-carrying capacity of the machine, and 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 staff at VTD [ARL's Vehicle Technology Directorate] has demonstrated that it should be possible to detect the onset of rotating stall/surge for a combined axial/centrifugal compressor machine. . . . The next step needed to take advantage of this phenomenon is to gather much more information on these precursor signatures. Such information will allow modifying the engine controller so that it can recognize the impending difficulty and take corrective action.[2]

After the appearance of the 1999-2000 assessment, ARL provided approximately $500,000 per year

[2]NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory*, p. 16.

for a 5-year period for conducting and transitioning this R&D. The Vehicle Technology Directorate (VTD) has already made significant progress in defining many important details of the program, from both experimental and analytical perspectives. The Board is generally pleased with the progress demonstrated to date but offers three further suggestions for VTD consideration:

1. The Board strongly recommends that VTD consider the incorporation of a control system modification that could respond on a time scale representative of the event, as a prudent backup approach to VTD's planned use of gas injection to move the engine out of the stall/surge regime. The Board also urges VTD to solicit advice from the manufacturer of its test engine to guide any such planning for modifications to the control system.
2. The Board suggests that the researchers may wish to take a careful look at the program time line as currently envisioned to be sure that it will meet their objectives. The Board recommends that VTD solicit advice from the engine manufacturer in the structural design area to be sure that the planned modification to the engine for injection of gas is not a safety hazard.
3. The Board supports the effort initiated by VTD to involve Mississippi State University (MSU) in validating the computer code MSU TURBO using National Aeronautics and Space Administration (NASA) stall inception data. The Board suggests that VTD carefully prioritize the planned code developments in terms of the likelihood that they will produce real contributions, at useful points in the time line for the experimental program, for understanding the flow physics involved during stall and recovery through flow injection.

Continued Improvements to the Zahl Physical Sciences Laboratory

Another opportunity identified in the 1999-2000 Board report stemmed from the outstanding quality of the then-new Zahl Physical Sciences Laboratory in Adelphi, Maryland. The laboratory's sophisticated facilities for the fabrication of semiconductors and microelectromechanical systems (MEMS), material characterization, and electrochemistry impressed the Board as having great potential for world-class research. The Board still finds the Zahl Laboratory and its facilities to have great value and potential. The laboratory is now fully occupied, mostly by SEDD, and is functioning well. Originally planned for no better than class 1000, the clean rooms have been upgraded—some space to class 100 in 2001 and some to class 10 in 2002. The necessity for continuous improvement of the facilities in order to avoid obsolescence was articulated in the Board's 1999-2000 recommendations, and SEDD's aggressive response—begun even before the laboratory was completely occupied—is to be highly commended. The problems of properly balancing the number of scientists and engineers with an appropriate number of well-qualified support/technician personnel have been continuously addressed by SEDD management as the Zahl Laboratory has come into full operation, and the balance seems to be moving in the right direction.

The MEMS facility within the Zahl Laboratory, now fully functional, has begun to exploit its combination of comprehensive and up-to-date facilities and DOD recognition. (It has been designated the lead DOD laboratory for piezoelectric-based MEMS devices.) Adding to the basic piezoelectric-based device efforts that were its original focus (e.g., nanoscale miniature mechanical resonators for MHz/GHz precision frequency filters), the laboratory has started several projects focused on the fabrication and characterization of nanotechnology quantum dots and wires. In addition, some early exploration of the potential of "molecular electronics"—a combination of electrically conducting organic molecules with nano-arrays for attachment and the addressing of individual molecules as elementary logic components—has been added to the program. Continuous exploitation of this unique resource along these lines is an appropriate challenge and is strongly encouraged.

Rising Profile of ARL's Millimeter-wave Technology Work

Another opportunity discussed in the Board's 1999-2000 report arose from the observation that SEDD already possessed all the capabilities necessary to be considered DOD's lead laboratory for millimeter-wave (MMW) technology and had the opportunity to take on a leadership role in the MMW community. MMW technology is particularly well matched to Army applications: because of the high MMW frequencies, reasonable transverse radar resolution can be obtained from antennas small enough to be compatible with Army vehicles (e.g., Future Combat System [FCS]), while the relatively low powers that characterize MMW sources are not often a serious limitation as range requirements are typically modest owing to terrain obscuration. SEDD has been active in MMW technology for a long time, and with its industrial and university collaborators (mostly through ARL's Advanced Sensors federated laboratory consortium and the subsequent Advanced Sensors CTA), it has produced state-of-the-art monolithic microwave integrated circuit (MMIC) components at MMW frequencies. It has demonstrated fully operational MMW radars, and developed and demonstrated a passive MMW imaging sensor (camera) capable of "seeing" through a range of obscurants, such as foliage, fog, and smoke. In addition, SEDD maintains a unique outdoor MMW test range, where target signatures and environmental effects can be experimentally investigated and verified.

SEDD has responded proactively to this opportunity by initiating an extensive effort in technical outreach through seminars, workshops, and symposia. In 2001, SEDD sponsored a passive MMW workshop that was attended by military users and an international group of passive MMW system experts, and a SEDD staff member cochaired the 2001 conference of the Society for Photo-Optical Instrumentation Engineers (SPIE) on passive MMW imaging. In addition, SEDD personnel now participate in a number of key MMW-related groups, including the TG14 NATO Group, a Federal Aviation Administration (FAA) design review team, and the Board for Aviation Security Research and Development. SEDD is to be commended for this positive response and should continue to enhance its status as DOD MMW lead laboratory.

Examples of Responses Requiring Further Action

One concern raised in the Board's 1999-2000 report that has not yet been fully addressed relates to staff insularity. While there are excellent examples of ARL S&Es with extensive outside contact and of willingness to leverage outside progress, the Board still sees scattered resistance throughout ARL to making use of knowledge generated elsewhere. For instance, SLAD's intense efforts to come to grips with survivability/lethality questions for the Army's Future Combat System, which require it to develop an expanded mix of skills, should include more leveraging of outside efforts. The FCS raises questions of information warfare, systems-of-systems analyses, vulnerabilities of the tactical internet, and so forth—problems that are fundamentally different from traditional ballistics problems. Thus, the Board recommends that SLAD forge new alliances with academia and industry in response to these new issues. Just as SLAD has a very good working relationship with suppliers of armaments, it should begin to forge the same kinds of alliances with suppliers of the new digital technologies. In addition, SLAD should build connections with an intellectually and geographically more diverse group of academic institutions whose research would help SLAD in its mission. (The connectivity of the staff is discussed at greater length in the next chapter.)

Another concern expressed in the 1999-2000 report—that ARL strive for an appropriate balance of exploratory work and more applied work and for enough flexible funding to allow follow-through on critical topics that might otherwise not be investigated—has met with some success, but improvement is still desirable. An appropriate balance would allow ARL to explore topics that provide a foundation for advances beyond the Objective Force, to serve as a "marketplace" where a broad spectrum of innovative research ideas are examined and filtered in order to make the Army a "smart buyer" of emerging technology, and to provide useful inputs to the Army-specific R&D program. Technological superiority is an important concern of the U.S. Army, and enabling that superiority is ultimately what ARL is all about. Superiority is founded, to a large extent, on the strength of, and continuing commitment to, basic research. Over the long term, high-risk/high-payoff basic research (as contrasted with research that tends to be more developmental and incremental) is what creates the opportunity for leapfrogging advances in Army technology.

Such high-risk research is also important because it keeps the Army cognizant of advances in important areas of research that have the potential of someday leading to technologies of value to the Army. This cognizance on the part of the Army positions ARL to quickly ramp up the needed R&D efforts when it is appropriate to transition such frontier research toward an implementable technology. Because ARL's basic research programs support many of its postdoctoral researchers and its collaborative efforts with academic S&Es, those programs are also the breeding ground for many of the laboratory's future leaders, those people with solid R&D credentials and a long-term vision of Army technology. The percentage of financial resources available for basic research is of necessity limited, and for that reason these resources should be protected and not allowed to be siphoned off for other projects that are not high-risk/high-payoff.

ARL agrees with the need for balancing its R&D portfolio and for pursuing high-risk/high-payoff basic research. In response to the 1999-2000 Board report, several directorates quickly became more aggressive about funding projects that are clearly exploratory in nature (e.g., SEDD's research with "cold atoms" at 0.001 K and with spintronics, CISD's explorations of quantum computing and linguistics, WMRD's research aimed at ultimately designing materials from first principles, and work on cognitive foundations of performance in the Human Research and Engineering Directorate [HRED]). However, it can be difficult for any R&D organization to strike the right balance between boldness and pragmatism. The Board recommends that ARL continue to examine how well it is achieving that balance, asking of each candidate topic for exploratory research whether ARL can truly contribute, whether doing a research project is necessary in order to stay abreast of developments, whether the topic resonates with other work in the respective directorates, and whether the topic has a chance of leading to Army-relevant technology within a reasonable time frame. The Board was not convinced, for instance, that these questions had been asked in regard to a CISD project on quantum computing and communications that the Board's panel for CISD was briefed on in the summer of 2002, and therefore the Board still considers the response to its 1999-2000 recommendation to be in need of attention.

Looking more broadly at ARL's success in balancing long-range and nearer-term work, the Board notes that SEDD, in particular, has been faced with this issue because of a strongly increasing demand for customer R&D (e.g., from DARPA). SEDD now faces a classic R&D conundrum of keeping the customers happy with near-term applications of technology while continuing the more fundamental, future-oriented research that will enable tomorrow's applications but is often not yet recognized by customers as being useful. The pressures to back off from long-term research in favor of immediate applications are often intense, but they must be resisted. The Board points to SLAD's investment over the years in its Ballistic Research Laboratory Computer-aided Design (BRL-CAD) software and related computational modeling tools as a good example of a directorate taking a longer-term view than that of its customers, and consequently developing a valuable leap ahead in capabilities. Resolving this tension between satisfying customers and laying the groundwork for the future requires attention, good judgment, and appropriate guidance from management. SEDD's managers seem to be evaluating their options intelligently and in agreement with the advice in the Board's 1999-2000 report, but it remains to be seen how well they will succeed.

A final indication of ARL's skill at balancing long-range and nearer-term work will be seen in the way that it manages the five Collaborative Technology Alliances (CTAs) established in 2002. The CTAs, a follow-on to ARL's former Federated Laboratory consortia, are collaborative R&D consortia, initially funded with 6.1 (basic research) money, that involve Army laboratories, industry, and academe. In most cases, the CTAs are led by an industrial organization. While this leadership has the positive aspect of bringing a utilitarian perspective to the activities of the partners, it also might tend to draw the CTAs away from some of the more high-risk research that would ordinarily be the province of 6.1-funded activities. Thus, there is a risk that by channeling a substantial fraction of Army 6.1 funding through the CTAs, the Army will also undercut its investment in true high-risk/high-payoff research. ARL must guard against that possibility. The Board has a mandate to assess the quality of the CTAs' R&D, and it will be attentive to the possibility that their work might tend toward lower-risk activities.

The design of the CTAs indicates that ARL is taking advantage of lessons learned from the Federated Laboratories and from its other experience at facilitating the transition of basic research toward Army-specific knowledge. For instance, the CTAs were set up with a provision to extend successful consortia for an additional 3 years beyond their nominal 5-year lifetime; this longer period was recommended in an early report from the Board. Another promising development is that the CTAs' contracts have a provision for adding 6.2 funds if and when transitioning tasks are identified. This was not the case for the Federated Laboratories, which sometimes encountered difficulties in research transition. Another strong point of the present configuration of the CTAs is that there is a research advisory board (RAB) for each CTA, which includes representatives from other services. The Board applauds the creation of this RAB structure because of its potential for enabling greater cross-fertilization among the services and for reducing duplication. These boards can also give the consortia a broader view of potential technology-transition possibilities. It is hoped that through such an arrangement the lack of knowledge of other activities can be minimized, leading to a more optimal result, and that the comprehensiveness of research approaches can be enhanced. It certainly will aid in reducing the "not invented here syndrome" as well, which is a tendency common to numerous technical organizations across government and industry. Finally, a clear understanding was established at the start that the CTAs will be reviewed for technical quality by the ARL Technical Assessment Board panels, thus allowing an additional avenue for other technical inputs and perspectives.

General Level of Responsiveness

In spite of some instances of ongoing problems, the Board wants to stress that it continues to see improvements across ARL, and it believes that all ARL units are generally responsive to the external assessments. In fact, the panels reviewing VTD and SEDD explicitly noted the quality of their interactions with their respective ARL directorates. The panel reviewing VTD, after its 2002 meeting, concluded that this was one of the most valuable reviews it had conducted at ARL: the presenters were generally well prepared, they allowed ample time for questioning, and the interchange between presenters and panel members was constructive. Several members of VTD volunteered that they felt the review panel was making a conscious attempt to help them improve their capabilities, which is indeed the panel's goal.

In the case of the panel reviewing SEDD, its steadily increasing rapport with SEDD's technical staff has helped the panel provide more pertinent assessments. Evidence of the productive openness between SEDD staff members and the panel includes the free involvement of panel members in the annual planning workshop that SEDD holds for its customers. (WMRD has also involved its panel members in its customer workshop.) Through these workshops, panel members are exposed to all of the directorate's activities and plans. The nature of this relationship between panel and staff has also given the panel a clearer understanding of the outstanding job accomplished by SEDD, which has evolved over recent years into an R&D organization that provides world-class leadership in a number of areas.

SOME SIGNIFICANT ADVANCES SINCE THE 1999-2000 REPORT

The Board is pleased to see important R&D progress in the 2 years since it wrote its previous assessment report. The following subsections note particular advances that illustrate some of the excitement of ARL's recent work and offer just a few concrete examples of the return on investment provided to the Army by ARL. (This short list is by no means exhaustive, and the omission of other activities should not be viewed as a negative statement about them.)

Leadership in Radar and Ladar Imaging for Foliage Penetration

Over the past few years, SEDD's excellent and steady progress in radar and ladar imaging for penetration of foliage and other obscurants has laid the groundwork for major programs in related areas at the Defense Advanced Research Projects Agency. These DARPA programs, which marshal resources well beyond those available to SEDD, have the potential of leading to developments of great value to the military. The $40 million of DARPA funding that SEDD received in Fiscal Year (FY) 2002 is concrete recognition of the quality and relevance of SEDD's leadership in these areas.

Materials Research with Important Potential for the Army

WMRD has continued its R&D in a novel material that might enable the use of phased array antennas, which could be of great value to the Army. These antenna systems have the important advantage in battlefield situations of presenting much smaller electromagnetic signatures than those of current designs. However, widespread use of these systems is limited by cost, with a typical array for a radio access point costing more than $500,000. A materials research project within WMRD developed a unique processing route for the ferroelectric ceramic used, barium-strontium titanate (BST). WMRD researchers succeeded in controlling the morphology and purity of BST powder using surfactants and careful control of acidity. Complex three-dimensional structures needed for a phased array were then made using a combination of lost wax investment casting and ceramic gelcasting. After suitable process optimization, it is expected that the cost of a phased array antenna made by this process could be reduced to about $50,000—providing an excellent example of how materials research can be a cost-effective technology enabler.

Another example of enabling research, not quite as far along, is WMRD's work toward a processing method for structural polymer composites. It is quite certain that, because of their high strength-to-weight ratio, polymer-based composite materials will play a major role as structural parts in rotorcraft, unmanned aerial vehicles, and FCS ground vehicles. Composite armor also will increase in importance. A major barrier to wide-scale application of polymer composite materials is their high cost relative to that for metals. This expense comes about chiefly because the polymer molding process that is used to make the parts—manually laying up plies and then compacting the composite slowly in a heated autoclave—is much slower, more complex, and costlier than metal casting or sheet metal stamping. Some type of liquid resin molding, if it could be properly engineered, would be a more practical process, and that is the idea being pursued by WMRD. In close conjunction with the University of Delaware Center of Excellence on Composites funded by the Army Research Office, WMRD has made great strides toward developing a more economical, high-quality processing method for these structural polymer composites.

In working on this method, WMRD researchers recognized that the ability to visualize the resin flow around the fibers (which account for much of the strength and rigidity of the composite) is a necessary first step toward ensuring complete fill and the absence of voids. (Previously, resin flow around the fibers could be visualized by using transparent tooling, but this limits observation to the surface region.) Computer modeling software called SMARTweave (U.S. Patent 5,210,499) was developed at WMRD to provide three-dimensional imaging of resin flow. WMRD also has developed and patented a modified vacuum-assisted resin transfer molding (VARTM) process known as FASTRAC. The technique works by using a primary bag and a secondary, “corrugated” vacuum bag to control resin flow through the bed of graphite fibers or fiberglass. The secondary bag creates channels through which the resin flows. The rate of flow is much faster than in the permeation type of Darcy flow found in the standard VARTM process. After the polymer sets, the secondary bag is peeled from the part, leaving a minimum of waste material. By contrast, in the standard VARTM process there is considerable waste material in the form of resin-contaminated sheets, which must be disposed of after each run. This waste material creates an environmental hazard as well as a cost penalty. In the FASTRAC process, the set-up steps are reduced by two-thirds, and there is a 40 to 80 percent reduction in set-up labor and a 40 to 50 percent reduction in waste material. Because of better flow distribution, there are fewer dry spots where the resin has not penetrated the fiber mat. FASTRAC has reached the level of maturity at which it is attracting considerable interest from defense contractors and others.

Another ARL success story since the Board’s previous report also relates to the processing of composites; this time the work was performed by a researcher in VTD. The example is of particular interest because the results were achieved with a small budget, and they demonstrate the payoff that the cleverness and insight of a single investigator can have. The VTD investigator demonstrated significant progress in the construction and application of macro fiber composite actuators. In past years, patches of piezoelectric fibers were made by way of extrusion. However, extruded material has nonuniform properties, cannot be stacked uniformly, and is very slow to make. The VTD investigator developed a technique to cut piezoelectric wafers along parallel lines to make very reproducible and much less costly patches that were subsequently encapsulated in Kapton. These units turned out to be uniform and able to sustain high voltage without arcing, and they produced the desired performance when placed on airfoils. (An example of these devices operating on an airfoil was provided for the panel.) The overall effort was considered by the panel to be exceptional. These wafers are potentially useful in many areas of ongoing activity within the research and application community as well as within other directorates of ARL.

Optical Communication

The CISD work in optical communication is excellent, and significant progress has been made in the past 2 years. Optical communication offers high capacity and limited spatial diffusion (relative to radiofrequency communications). These attributes are important as the Army moves toward information dominance in 2010 and after. The work also builds on ARL’s capabilities in adaptive optics. Further, it is more than just a theoretical or simulation study: solid experiments are being performed and evaluated. The addition of an optical test range at ARL is significant for moving this work forward. The Board was not clear about whether other groups within DOD that are interested in optical communication know about ARL’s work in this area. In particular, the National Security Space Architect’s office is examining options for optical communication between satellites, from satellites to unmanned air vehicles, and from satellites to ground. Similarly, the Board did not have an opportunity to examine whether ARL's experts in optical communication (in CISD) and its other experts in optics (in SEDD) are in good communication and whether their programs are coordinated. The Board recommends that ARL check that these internal and external ties are being pursued.

Crack Growth Modeling

Another long-term effort that has not been discussed in previous Board assessments is VTD's effort directed at physics-based modeling of threshold fatigue crack growth for metallic materials. The crack closure problem is explored on a detailed scale at the crack tip. Although the mechanics community has performed considerable research in this area, there remains a fundamental lack of understanding of the fatigue behavior of short cracks. The use of high-resolution strain mapping techniques at VTD should yield new insights into the dominant mechanisms of crack closure, which in turn should provide guidance for life prediction models. This work has the potential to be fundamentally important. An analogous VTD effort relates to fatigue life methods for metallic rotorcraft structures; it addresses the fatigue from small cracks and is of importance to the Army. The results have a direct benefit to the large existing fleet of rotorcraft and many components on future designs. The methodology includes an excellent mix of aircraft usage data, analytical approaches, and data correlation.

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Connectivity

As noted in its 1999-2000 report, the Board believes strongly that Army Research Laboratory S&Es should be encouraged to interact with S&Es doing related work anywhere—in their own unit, in other units of ARL, or outside ARL. External collaborations are a very valuable mechanism for expanding a laboratory's efforts at relatively low cost. Collaborations, whether external or internal, also help to build a healthy research environment in which all research staff are more likely to contribute with greater insight and depth of understanding. The Board has seen clear improvements in this area, but it urges ARL to continue to encourage interaction with other organizations doing related work outside ARL or DOD—for example, DOE or the academic community, to name but two. It is suggested that the staff make other communities more aware of Army interests through such efforts as more presentations and visits to outside laboratories and more in-house seminars by invited outsiders. The Board points out that a strong internal seminar program is also important for encouraging increased internal collaboration across ARL units, although it did not evaluate the existing program, and so it cannot state whether that program needs augmentation. ARL might also engage the Army Research Office's European and Asian offices to a greater degree in order to learn more about international developments of potential benefit to the Army.

EXISTING BENEFITS OF AND FUTURE ENHANCEMENTS TO CONNECTIVITY

The Board notes the numerous exceptional collaborations that already exist between ARL directorates and external academic institutions, such as WMRD's collaborations with the University of Delaware's composites research program and with Rutgers and Johns Hopkins Universities in ceramics, or SEDD's microelectronic research collaboration program. However, the directorates should be cautioned not to rely only on institutions that are geographically closest, for these may not be the optimum resources in academia for a directorate's purposes.

On several occasions, Board and panel members have been impressed with the willingness of some directorates to respond to contacts suggested by Board and panel members for their knowledge of research and resources that could be brought to bear in a meaningful manner with respect to Army interests. ARL also took a useful and creative step toward breaking down internal boundaries by requesting that high-level people from each directorate participate in each panel review meeting. This is a good way of disseminating information about each directorate throughout ARL and of maximizing the value gained from the preparations for panel meetings. At these review meetings, high-level staffers receive 2 days of technical briefings about a directorate other than their own, which requires an investment of time that would not likely occur without explicit recognition of its value and encouragement from ARL's top management. It is an important step, because the Board still observes instances in which ARL directorates are not sharing expertise as much as they could—for example, by coordinating the knowledge and planning with respect to information assurance that exist separately in CISD and SLAD.

As examples of connectivity, consider how WMRD contributes to the goals of equipping the mobile soldier with an enhanced lethality capability while providing the downsized combat vehicle with survivability through nonconventional methods. Even though expertise within WMRD is contributing importantly to these goals and WMRD might be capable of pursuing these efforts independently, the work is strongly connected with developments at Eglin Air Force Base, NASA-Langley, and the University of Texas. Many years of basic research at WMRD and its predecessor organizations on ballistics and weapons systems have provided the knowledge base for a science-based design of a family of smart munitions, and execution of the program involves collaboration among four branches in all three WMRD divisions. The modeling includes the failure modes of the electronic components of smart munitions, developed in conjunction with the University of Maryland. Because WMRD has invested many years of work in validating and verifying computational codes for ballistics applications, it has been able to apply these rapidly and effectively in the development of new design tools for a family of gun-launched and rocket-propelled smart munitions. This multidisciplinary work involves dynamic structural analysis coupled with fluid dynamics effects, interior ballistics, and computational electrodynamics.

Another example of connectivity is the Human Research and Engineering Directorate's good connections to the relevant modeling community. In the soldier-centered design tool program, a systematic "gaps analysis" was completed by means of a comprehensive survey of the field, showing a deep understanding of community modeling activities. Productive interactions among those doing related work at HRED and beyond could be further enhanced in the following ways:

- Share, across users, understanding of the assumptions and limits of models being developed and employed. Invite users to question the models and their assumptions.
- Share models developed at HRED with potential users outside the directorate. For example, make models such as IMPRINT available to the Human Systems Information Analysis Center (HSIAC), and create awareness of them through information in HSIAC publications.
- Play a leading role in collecting and maintaining soldier performance data that are applicable to many other models, in the Army and elsewhere. To fulfill that role, HRED would need a resident database expert who maintained data and formatted them for use by others, while maintaining awareness of the capabilities and requirements of a variety of models; or, it might elect to work with HSIAC to accomplish the same goals.
- Pursue connections with the extramural community, including related program activities in the Multidisciplinary University Research Initiative (MURI) collaboration with the CTA for Advanced Decision Architectures, and interactions with the ACT-R community, attending their workshops and sharing work products. (ACT-R is the software implementation of a theory of cognition called Adaptive Character of Thought [ACT].)

SEDD's S&Es appear to be in effective contact with the Army and other elements of DOD, and they are also well connected to the wider community of academic research and industry through such mechanisms as MURIs and CTAs. In addition, various individuals in SEDD participate on a number of key government tiger teams and steering boards, which keeps SEDD in the forefront of current military technology.

All ARL units seem to have strong relationships with their Army customers at Research, Development, and Engineering Centers (RDECs) and elsewhere. Each spring, SEDD and WMRD conduct joint planning meetings with their customers to establish the details of the next Fiscal Year's technical plans. Several years ago, after one such meeting, 5 to 15 percent of SEDD's plans were altered to accommodate its customers' responses to the preliminary plans. However, during the past 2 years, no substantial replanning has been necessary, suggesting that SEDD is now so well coupled to the relevant RDECs that the requirements of these centers are automatically incorporated from the start through an extensive and continuous joint planning process. VTD's coupling to Army needs has come about through its close ties with the Army Aviation RDEC, and VTD also has developed clear ties to NASA and to the rotorcraft industry. More recently, a VTD investigator is now planning a sabbatical leave with the FAA Technical Center, which should be a particularly helpful interchange. SLAD has developed close coordination with the Army test and evaluation community and the Army's program managers and project executive officers. HRED's ties to Army needs come about in part through the directorate's presence on numerous Army facilities nationwide; in fact, a large proportion of HRED staff provide direct support to Army development programs. CISD, meanwhile, maintains connections through its joint work with the Army Communications-Electronics Command (CECOM), through the CTAs in which it is involved, and through Army users of the Major Shared Resource (supercomputing) Center that it administers.

ARMY RESEARCH OFFICE

The Army Research Office (ARO) is the principal ARL unit responsible for ensuring that the Army has an awareness of long-term research developments of potential relevance to the Army. While ARL's in-house units seem to have a good awareness of one another's basic research activities, it is not clear that all the directorates take appropriate advantage of ARO's contacts and basic research. As the ARO has become more fully integrated into the overall ARL organization, the extent to which its 6.1 funding is coordinated with and exploited by the rest of ARL is not yet clear to the Board, which does not directly review ARO's work. In the 2002 review of SEDD, explicit reference was made to joint SEDD-ARO activities, and SEDD and CISD have taken some very positive steps to strengthen and optimize their relationships with ARO (e.g., a SEDD-ARO workshop was held in early 2002, and CISD had conducted a similar joint review in 2001). WMRD appears to have notably good ties with ARO. HRED's appropriate counterpart organization is the Army Research Institute (ARI), which is part of the Office of the Army's Deputy Chief of Staff for Personnel, not part of ARL or the Army Materiel Command. There are ample links between HRED and ARI. This conscious interaction with ARO and ARI is to be commended and should definitely be encouraged throughout ARL in the future.

The Board will do its part to encourage the kinds of contacts described above by questioning ARL units about their involvement with ARO or ARI initiatives and programs. In order to improve the coordination between its in-house laboratories and ARO and ARI, ARL should consider organizing and conducting more community workshops to define, in specified technologies and within the context of Army interests, the state of research and the primary areas of short- and longer-term research opportunity. Effective use of this sort of workshop approach could also improve the definition of coordinated programmatic thrusts, and that in turn could make them easier to launch.

4

Opportunities

ARL has a number of strong and/or unique capabilities that could be further exploited or profitably expanded to the benefit of the organization itself, the Army as a whole, and in some cases the technical community at large. It is also positioned to play a greater leadership role in some areas, for the benefit of the Army overall. This chapter explores some of these striking opportunities.

FACILITIES

The Board's 1999-2000 report pointed out that the Zahl Physical Sciences Laboratory "is an obvious opportunity from which ARL can benefit."[1] This assessment appears to continue to hold in 2002, as was pointed out in Chapter 2 of this report. The same is true for the Rodman Materials Laboratory and the DOD Major Shared Resource Center (MSRC) at Aberdeen Proving Ground, Maryland, which were noted in 2000 as being "excellent facilities that provide analogous opportunities for ARL."[2] The Board had developed some concerns in the intervening years about some ARL units not taking maximum advantage of the MSRC, but by 2002 the Board saw little evidence of ARL staff failing to take advantage of this resource.

Another issue, beyond ARL's control, is the replacement of SLAD's unique experimental facility, the Electromagnetic Vulnerability Assessment Facility (EMVAF), at White Sands Missile Range, New Mexico. The EMVAF was destroyed by fire on January 11, 2001. The building and most of its equipment were lost, as well as the capability to perform what seem to be critical experiments for the Objective Force. The loss of this capability precludes timely completion of many survivability and lethality assessments. Given the risk of electronic warfare attacks on systems employing digital technology, it is critical that this capability be restored as soon as possible. Only a new EMVAF can provide the Army with the ability to benchmark, and thus quantify, system vulnerabilities; simulations, which cannot be properly validated without such a facility, are not an adequate substitute. The Board understands that construction funds of approximately $35 million are slated to be provided in FY 2006. The development of a new facility for EM vulnerability assessments would provide ARL with an opportunity, if construction proceeds apace or is accelerated, for having a very beneficial influence on the design of the FCS.

[1]NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory,* p. 15.
[2]NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory*, p. 16.

HRED has received funding and is developing a major simulation facility, the Tactical Environmental Simulation Facility at Aberdeen Proving Ground, that is designed to support quantitative studies of soldier reactions to realistic acoustic and visual environmental stimulation. Proposed studies in this simulator are currently being designed. The facility has great potential for leading to more realistic assessments of soldier performance. The Board's Soldier Systems Panel, which assesses HRED, has some concern, however, about the staffing plan for this facility. Expert staff should be identified who can develop cost-effective experimental designs for such a facility in order to avoid the risk of producing experiments with suboptimal designs.

CRASH DYNAMICS

The developing capabilities of VTD in modeling crash dynamics and crashworthiness present an emerging opportunity to improve the safety of future Army vehicles. This analytical capability will be of critical importance if NASA closes its crash test facility at Langley, Virginia, as is currently planned. At this time, though, the state of the VTD analytical capabilities is not such that reliable crash simulations could be carried out in the absence of an experimental capability. If VTD intends to create useful simulations, it will have to attack this challenge more aggressively.

Among other actions, this would call for VTD's crashworthiness investigators, in particular those engaged in modeling and simulation, to leverage their efforts by examining in greater depth similar work with which they are familiar that is performed in the automotive community. The crash trajectories are most certainly different for a helicopter and a car; however, the challenges faced by research in crash dynamics and the methodologies for addressing these challenges in the context of helicopters and cars are similar in many ways. Better use could also be made of outside data (obtained from, for instance, automotive crash tests), which could be utilized to improve the validity of vulnerability assessments.

Modeling crashworthiness demands a great deal of fidelity, because one cannot know a priori which physical details will have major effects during a specific crash sequence. An additional complication is that one cannot generally perform a virtual test on just a substructure, because the interactions between structural components might be critical; many discrepancies between modeling and physical tests are due to judgments that were made about how a virtual model could be uncoupled into substructures. Both of these reasons are arguments for VTD's making more use of the Army's high-performance computing for crashworthiness simulations.

PHYSICS-BASED MODELING OF MECHANICAL BEHAVIOR

The VTD activity on nondeterministic methods and reliability-based design incorporates a combination of problem parameters and their statistical distribution, and how they interact to provide an estimate of the overall probability of failure. The effort includes an excursion to fuzzy logic and "possibilistic" estimates. The panel agrees with VTD that the results of the effort to date are useful and reasonable for a simple lap joint. The next phase of the effort must address a more complicated problem. The results of this work could have real engineering implications for tire failure estimation.

The development of reliability-based computational tools can have a positive impact on Army vehicle readiness if they are successfully incorporated in a risk-based structural design methodology. Moreover, this area could potentially cut across numerous other areas of interest to VTD and beyond. It should yield useful and computationally efficient tools for designers to assess the relative importance of the many factors that influence structural failure, and thus allow them to focus their efforts on the most important factors at an early stage in the product cycle. The usefulness of these tools (especially those based on possibilistic methods) will only become evident once the tools find applications.

The Board's Air and Ground Vehicle Technology Panel, which assesses VTD, supports the systematic development and validation of robust computational methods for analytical treatment of system uncertainties, as well as the planned future applications to composite airframe components. Continued close interaction with industry is encouraged to develop realistic failure modes based on experience in the field. The panel recommends further development of multifailure modes methodology and continued coordination with NASA's Progressive Failure Initiative group.

The VTD effort in coupled-finite element methods is designed to develop an efficient computational framework for solving crack propagation problems. The idea is to combine a meshless method in the regions of the cracks with a standard finite element method in the regions without cracks. Indeed, meshless methods offer significant advantages over standard Galerkin methods for crack propagation problems. However, the panel suggests that the investigators might want to consider applying the meshless method to the entire domain, since this method obviously handles equally well "plain vanilla" stress analysis problems.

The investigators appear to be aware of recent developments in the field of meshless methods and plan to build on them. While the work presented to the panel was in its early stages, it is promising and should demonstrate a quality comparable to similar efforts in competing institutions, particularly if the final method is implemented on a powerful computing platform.

MICROMETEOROLOGY

ARL has an opportunity to create a unique R&D program in micrometeorology, of great relevance for the Army, following its success with the fielded Integrated Meteorology System (IMETS). As of summer 2002, there was some evidence that the Army's research efforts in atmospheric science were beginning to drift, though a subsequent ARL-sponsored workshop demonstrated that ARL recognized this tendency and was beginning appropriate steps to counter it. The Board and ARL agree that a renewed focus on micrometeorology is appropriate for the "post-IMETS" program.

That there is considerable opportunity to focus research in the area of micrometeorology is evidenced by the fact that the last national planning document for the atmospheric sciences, the National Research Council report entitled *The Atmospheric Sciences: Entering the Twenty-First Century,*[3] did not cover boundary layer science in a manner consistent with the capabilities that are now needed for planning national emergency responses or Army operations. Because so many other federal programs are also pursuing meteorological research, with greater resources than those available to ARL's meteorologists, ARL must be especially careful in formulating future plans that complement those larger efforts and that will provide maximal value to the Army. Fortunately, as ARL is aware, micrometeorology is not only the scale of primary interest to the Army, it is the scale that is conspicuously absent from most other research programs.

Therefore, the Board recommends that ARL's meteorology program exploit its particular capabilities and tradition of contributing to the development of unique field experiments and databases that can be used not only for analytic studies and model development and validation, but also for testing of the Army's environmentally sensitive communications and weapons systems. Given the obvious failure of current surface boundary layer models to replicate major features of behavior in complex terrain,

[3]National Research Council. 1998. *The Atmospheric Sciences: Entering the Twenty-First Century*. National Academy Press, Washington, D.C., pp. 79-82.

including urban settings and forested canopies, and especially noting the failure of all models to provide good descriptions for coastal regimes, it is clear that research on improving understanding of the appropriate physics must be accelerated. Field validation of computational research, for instance, could be conducted by ARL in "semi-complex" terrain, such as the shoreline environments at ARL's Aberdeen and Blossom Point locations.

However, it is obvious that ARL cannot do all of this work itself. One possibility to explore would be for ARL to organize a consortium of research groups from other U.S. agencies, augmented by such academic researchers as may be appropriate (including those in fields such as fire research and wind engineering), to construct and implement a plan for future activities under the general heading of "boundary layer research for national defense." This plan would eventually entail the establishment of several ongoing field sites, to cover the range of conditions likely to confront the Army in future deployments. Each field center could well be instrumented to provide an ongoing and uninterrupted record of key variables. The intensive studies necessary to reveal and describe key processes could then cycle among these sites, thus substantially reducing the cost and the burden on the very limited cadre of experienced scientists in this field.

BATTLEFIELD COMMUNICATIONS

ARL could play a greater leadership role in the development of battlefield communications networks. While it appears that ARL is making progress in science and technology in this diverse problem area, through the multi-institutional CTA on communications and networks, there appears to be a need for ARL to provide expert guidance on the issues of communications standards and environmental effects.

Communications Standards

The Army seems to be gravitating toward a decision not to use IPv6 (Internet Protocol, version 6) as the network layer protocol for the proposed battlefield sensor network. In the Board's view, this is a serious mistake, and the Board recommends that ARL play an important leadership role by ensuring that Army decision makers understand the ramifications of such a decision. There are no important technical reasons for not using IPv6, and there are substantial practical reasons for using the standard Internet protocol. The real costs of not using IPv6 are the myriad of secondary issues: the cost of building and maintaining an isolated independent protocol, the inability to use existing platforms for the rest of the system, and the lack of measurement and management tools, to name just a few. The technical staff at CISD does not seem to appreciate how poor the choice of a custom protocol could prove to be.

Stripped to its core, the Internet Protocol is just an addressing package for packets. The routing algorithms are changeable, and, indeed, multiple routing algorithms are used throughout the Internet. This is definitely not to suggest that standard software implementations of IP, routing, network management, and so on, be imposed on the sensors in the field. However, the IP framework is very thin and open, and it easily accommodates a great deal of specialization. A very large part of the Army's needs could be experimented with and explored inside the IP framework. If those in CISD or others in the Army then find it necessary to develop new routing mechanisms or other variants, it is likely that their work will be useful to others who have similar problems, and their chances of exporting that work will be far greater if they use IP. The downside of not using IP is the enormous cost of developing all of the supporting infrastructure for monitoring, controlling, and so on, and the inability to use standard products for the parts of the system that are not power-sensitive.

It is conceivable that IP is too energy consuming in some very limited and specific contexts, although the Digitization and Communications Science Panel, which assesses CISD, was skeptical of this, and the possibility was not raised by CISD staff when the issue of IP came up. If the Army believes that this is the case, then non-IP protocols could be used in very limited situations and limited to very short paths. In network lingo, a non-IP path could be used for a single hop, essentially layer 2, but there is no need to build a full network with routing, network management, and so on, using an alternative to IP. The total amount of infrastructure required would be very large, and it is unlikely that there is a very close correlation between energy consumption and the network protocol when one looks at a full network. (An ARL project on reducing the energy consumption of IP would be an appropriate and feasible undertaking, if energy consumption is the primary reason the Army is avoiding IP addressing.) It is acceptable to consider using shorter packets and specialized protocols within very confined networks, but the design should be viewed as living within the larger Internet context, not completely apart from it. No matter how narrowly the Army defines its battlefield communications network and how vigorously it tries to make the case that it needs to be separate, the Army will inevitably stumble into reinventing a lot of things that come for free in an IP environment. The Army needs a keen awareness of this effect before plunging in, and ARL can be the “smart buyer” for these major decisions.

Incorporation of Environmental Effects

Given the extraordinary sensitivity of VHF and UHF systems to environmental conditions, especially in regions of complex terrain and shorelines, it is surprising that the Army’s R&D related to communications networks does not seem to address the problems of testing and validating system performance in a variety of weather conditions. CISD has the facilities and the connections to other Army laboratory facilities necessary to carry out the kinds of field-testing that are critical to the final design of prototype systems, and the fact that its meteorologists and communications experts are housed in the same directorate (CISD) is a bonus. CISD could make a significant contribution—one that could provide substantial cost savings to the Army and the defense community generally—if it promoted much earlier environmental testing and evaluation of research and prototype communications systems. (This same opportunity would also extend to other types of Army systems, not as closely linked with CISD.) Many of the technologies and systems developed by DOD’s research programs end up having very limited utility because they simply will not function reliably in other than very “friendly” and/or benign weather conditions. Thus, some additional investment in predicting the realistic performance of potential systems could result in huge savings in hardware development costs.

Given that the telecommunications CTA is quite new, there is still time to incorporate such fruitful collaborations, and the Board recommends that ARL do so.

IMPROVEMENTS IN WEAPONRY

A classic activity of WMRD, and its predecessor Ballistics Research Laboratory, is interior ballistics. This is the science of understanding what happens inside the gun tube from the instant the propellant is ignited until the projectile leaves the muzzle. Recent advances have included laser ignition of propellants, which is safer and more reliable than conventional impact or electrically initiated primers, and the development of two important computer models, NGEN and NSRG. NGEN is a multiphase (gas/liquid/solid), three-dimensional, computational fluid dynamics code that models solid propellant ignition, flamespreading, case combustion, multiphase flow physics, plasma injection and convection, and projectile/propellant interaction. NSRG is a Navier-Stokes-based code that provides high-fidelity computer simulations of complex missile propulsion systems.

Recognizing that it is time to make similar advances in energetic materials themselves, WMRD has initiated a major program on Insensitive High-Energy Munitions as part of the interservice National Advanced Energetics Initiative. A two-pronged approach is planned. One approach is to increase the energy available in the propellant gas by discovering improved energetic materials. The other is to find improved methods to tailor the gas generation rate to better match the rate of increase in containment volume as the projectile moves down the gun tube.

The search for improved energetic materials is being directed through the extensive use of computer-based quantum mechanical modeling. WMRD hopes by this means to be able to discover new energetic materials, or new structural forms of existing materials, and to do so in a way that is more expeditious than using standard organic chemical synthesis. Using quantum mechanical modeling, WMRD expects to be able to predict heats of formation, rate constants, density, and impact sensitivity. The Board encourages the use of advanced modeling methods, but warns that the correlation between quantum mechanical calculations of charge density and impact sensitivity is likely to be very unreliable. The Board urges increased communication with relevant DOE national laboratories, especially Los Alamos National Laboratory, that have done extensive work on computational chemistry and explosive safety. The Board believes that WMRD is putting too much emphasis on computer modeling, in this case to the exclusion of developing more efficient experimental screening tests. The electric flyer plate experiments being conducted are an exception to this statement and should be refined further. Here again, closer coordination with work done at Los Alamos should expedite progress at WMRD.

WMRD is charged with the responsibility for developing an understanding of the lethal mechanisms by which weapons systems defeat a target. Much thought and effort have been devoted over the years to this very complex physics and materials problem. Historically, the weapons have been engineered before a complete understanding of their physical mechanisms has been achieved (e.g., in the case of shaped charges and kinetic energy long-rod penetrators). The changing nature of threats, construction technologies, and targets (in addition to just armor plate) calls for an understanding over a full spectrum of lethality. The emphasis on soldier mobility requires lighter weapons of adequate lethality to defeat armor.

Significant gains have been made in the ability to understand lethality in recent years. Computational solid mechanics has become an invaluable tool for providing detailed analysis of penetrator-target interactions and of alternatives concerning weapon design options. However, many penetrator-defeat mechanisms depend on fracturing the projectile, and so an understanding of the failure modes and how to model them realistically is required. Adiabatic shear localization has been recognized as a dominant target failure mechanism in armor materials. WMRD has a long history of metallurgical analysis and analytical modeling of adiabatic shear bands, being the first to show that shear bands explained the superior performance of depleted uranium penetrators. Considerable effort has gone into developing a computational failure model for the formation and collapse of adiabatic shear bands (a very difficult problem because it involves attempting to model at a scale that is several orders of magnitude larger than the actual physical failure process). Careful thought is required concerning the appropriate experiments to validate the modeling, and renewed effort is needed to develop constitutive (stress-strain) models to describe the adiabatic response of the material. A good start has been made by WMRD, but efforts need to be accelerated in light of the urgency of developing more-mobile weapons of high lethality and acceptable survivability. An accurate and robust computational failure model of projectile and target failure is the missing step that would allow computational solid mechanics to achieve its potential as an engineering design tool for lethal and survivable weapons systems. This work requires close interaction between researchers in computational and experimental mechanics and materials. Two important steps toward achieving this objective are filling the leadership vacancies in

WMRD's Terminal Effects Division with appropriate permanent staff and increasing the level of interaction with DOE and academic laboratories.

DATA OF INTEREST TO OTHER RESEARCHERS

SEDD, HRED, and WMRD all have an opportunity in that they have access to real data (or can generate data) that would be both of great benefit to and an enticement to the outside community of researchers. Making the extra effort of organizing, maintaining, and promoting those data sets would be of benefit not only to researchers inside the Army but to researchers outside as well. The availability of such data would increase ARL's success as a crossroads for research. Thus, ARL may wish to consider a mechanism that would streamline and facilitate the tabulation and transfer of quality data.

SEDD has a very broad range of expertise in sensors of all kinds—electro-optical, radio-frequency, acoustic, seismic, electric, magnetic, and so on—and several field-test ranges available to it for testing the performance of single or networked sensors against a wide range of military targets in relevant environments. One of the greatest frustrations of the developers of algorithms (e.g., for automated target recognition, fusion of sensor data, and so on), both within and outside the military community, is the paucity of available, relevant, experimental sensor field data. There is a critical need for such data. Therefore, the Board suggests that SEDD, with its expertise and field-test facilities, could go a long way toward filling this vacuum. This definitely would not be an easy task, as there are a huge number of variables to be considered, data format standards to be established, and so on, and it all costs money. Inevitably, some data will be classified and thus not available to all. Still, it is a worthwhile endeavor to consider.

HRED can exploit its unique physical resources and associated professional expertise to study important Army issues related to soldier systems. The physical resources include a shooting range available for research on shooting, at which precise measurements can be made of variables relevant to shooting performance. A vehicle-driving course is available for testing human performance on prototypes of design features for Future Combat Systems. An impressive instrumented facility is available for studying situation awareness and other variables critical to military operations in urban terrain (the MOUT facility).

As noted in Chapter 3, HRED should consider taking on a leading role in collecting and maintaining soldier performance data that are applicable to many other models, in the Army and elsewhere. To fulfill that role, HRED would need a resident database expert to maintain and format the data for use by others, while maintaining awareness of the capabilities and requirements of a variety of models. (Alternatively, HRED could work with other organizations, such as the Human Systems Information Analysis Center, to accomplish the same goals.) However, the Board encourages HRED to continue to improve its methodology—with adequate sample sizes, design of tasks used in experiments, pre-training to critical performance levels, double-blind experimental designs, validation and sensitivity testing of models—to reduce the ambiguity of the data collected and to enhance the usefulness of results. One area in which investigators are clearly constrained in the rigor of their methodology (by time and resources) is that of applied, customer-supported work; at times they must rely on subjective evaluations, when performance-based studies would be more appropriate.

To a lesser extent, data also represent an opportunity for SLAD, in two ways. First, the Board believes that it might be more economical and reliable for SLAD to maintain a data repository and tools for customers to access data than to continue with the current system of distributing data to every customer. Second, if SLAD were to establish such a data repository, with helpful access tools, the effort might promote an improved community relationship between SLAD and the users.

5

Challenges

As was the case in its 1999-2000 assessment, the Board has identified a small number of issues that merit increased attention by ARL in the interest of improving the overall quality and/or effectiveness of the organization. Those issues are discussed in the following sections.

VULNERABILITIES OF THE DIGITAL ARMY

In its 1999-2000 report,[1] the Board commended SLAD's efforts to develop a capability in information operations vulnerability and survivability analysis, developing a staff and program almost from scratch over the previous 3 years. However, the challenges continue to grow, and SLAD's small ($400,000) budget for 6.2 work does not give it the latitude needed to explore these complex issues adequately. The Board concludes that ARL, perhaps due to external constraints, is not devoting adequate effort to the development of tools and understanding that are critical to the success of the Future Combat System and the Objective Force.

The FCS is envisioned as a highly networked set of manned and unmanned combat units that are much lighter than current systems. The use of the FCS by the Objective Force is intended to provide greater responsiveness and flexibility than are currently possible, in large measure through enhanced situation awareness and information sharing. The effectiveness of the FCS will require significant developments in operations and tactics (an effort outside the domain of ARL) and concomitant efforts within Army R&D organizations, especially ARL. It is gratifying to see that HRED is researching critical issues in situation awareness, and SLAD's core strength in the ballistic survivability of armored systems will certainly help in the design and testing of the FCS. However, it is also necessary that the networking infrastructure underlying the FCS perform dependably in very dynamic, combinatorially complex, and environmentally demanding conditions. Therefore, the analysis of survivability and lethality of the FCS will require more thorough consideration of human performance, network behavior, information assurance, and systems engineering.

As mentioned in passing above, HRED is addressing important issues relative to vulnerabilities of the digital Army, such as how information technology can best be used to support team information sharing. HRED research to date on information sharing has addressed a few variables at the pilot-study

[1] NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory*, pp. 19-20.

level, with continuing research planned. The Board encourages the expansion of this research, to encompass system design variables and team resource management issues, and the development and use of a larger repertoire of performance measures, some of which can be employed under laboratory conditions. Also, the coordination of this line of research with research on situation awareness being done under the Advanced Decision Architectures CTA should benefit both sets of investigators.

Findings from other HRED research convey an important message for the development of Objective Force warrior systems: cognitive load associated with information technology can affect soldier performance on fundamental tasks such as shooting. The Board recommends that future HRED work examine methods of improving task performance by reducing load or adjusting to it, that secondary tasks more relevant to soldier workload be employed, and that signal detection analysis be used to assess the results.

It is clear from the presentations and discussions with SLAD staff that SLAD's major near-term issue is to support FCS requirements, including system-of-systems work, information warfare, and electronic warfare, while continuing and perhaps expanding its world-class work in ballistics vulnerability analysis. SLAD's FCS work will require some combination of retraining and reassigning current personnel and hiring new people who are expert in relevant areas. This presents SLAD with a dilemma. Reassigning personnel and, in the process, diminishing important ballistics work would be unacceptable. Obtaining additional resources may not be an option because resources simply may not be available.

There may be a third alternative, however, in which SLAD works cooperatively with other agencies to pool FCS resources and to develop an ARL-wide (or Army-wide) survivability and lethality program for the FCS. Because the Board has no direct interaction with the other Army organizations from which resources may be drawn, or deep knowledge of the policy and doctrine issues within the ARL and of the Army leadership teams that may be involved, the Board has no specific recommendation on these alternatives, but it wishes to emphasize that a decision will need to be made.

SLAD management understands this dilemma. Most of the FCS-relevant presentations seen by the Board's panel for SLAD noted the need for enhanced emphasis on engineering performance assessments at the system-of-systems level. Nevertheless, the Board suggests that SLAD and ARL management teams consider the following six questions, among others, in planning to support survivability and lethality analysis for the FCS.

1. How will the Army couple the military science drivers for FCS performance to the engineering-level assessment of the networked FCS components? It seems likely that teaming between SLAD and the Army Training and Doctrine Command's Analysis Center (some of this teaming already takes place), or some similar arrangement, will be necessary. Such an arrangement should avoid the risk of SLAD's producing effectiveness analyses that are not relevant to the intended tactics, or the development of tactics that cannot be supported by the FCS equipment. The Board urges ARL to take the lead on this issue.
2. What is the correct balance within SLAD of technical skills required to support system-of-systems engineering-level analyses and the more traditional system and subsystem analyses? Work should begin on creating a strategic staff development plan, either within SLAD or in concert with other organizations. Are there opportunities to team more extensively with other directorates of ARL or with the Army's Communications-Electronics Command? If so, work should begin on developing memorandums of understanding with SLAD's prospective partners in FCS performance assessment.
3. Will the growing workload for ballistic analyses of the many new Army combat vehicles preclude SLAD from developing the necessary new technical capabilities required to analyze the

survivability and lethality of FCS? Will the Army recognize the increasing need to accomplish comprehensive survivability analyses in order to support the new force concepts?

4. What approach will SLAD take to redirecting internal resources from the support of legacy systems toward the support of systems critical to the Army's future? (This is a key issue if SLAD is going to create a place for survivability and lethality in the new force concepts.)
5. Who will develop the underlying model of vulnerabilities—based on a combination of hardware, situation awareness (however measured), networking, first-strike capability, and so on—that must supplant the engineering intuition that currently guides much of SLAD's work? The Army has a great need for solid understanding about information technology vulnerabilities and information assurance methods. In spite of valiant efforts within SLAD to develop that capability, the current level of activity within ARL is inadequate for the magnitude and importance of the problem. There is a need for a general theory to guide vulnerability assessments for a networked force. The engineering judgment that works well in identifying physical vulnerabilities in equipment is inadequate to the task of identifying the weak links, chokepoints, and vulnerabilities of complex networks, especially when those vulnerabilities might be traced to something nonphysical, such as a reduction in situation awareness.
6. In the course of its work, SLAD is sometimes limited to performing traditional vulnerability analyses, when system-of-systems issues are really the most important from a vulnerability perspective. How will SLAD, with its clear expertise in survivability and lethality analysis, bring these unanalyzed vulnerabilities to the attention of Army leaders? What type of mechanism might be created to do this?

The Board notes that addressing these questions will be uncomfortable for ARL; indeed, they involve significant new challenges with political, organizational, management, and technical dimensions. However, the success of the Army's Objective Force will depend critically on developing a detailed and technically defensible understanding of FCS performance, and that will not be possible without addressing the questions above.

VULNERABILITIES OF COTS PRODUCTS

An issue related to those discussed in the previous section, because materiel for the networked force will rely heavily on commercial computing and communications products, is that SLAD appears to have far too few resources to do stand-alone, in-depth analyses of complex commercial off-the-shelf (COTS) products. The Board recommends that SLAD rethink its role in this area, look for other sources for the information that it develops, and determine if its current approaches truly offer any unique benefits. At a minimum, it seems that SLAD needs to build a "community of interest" to deal with COTS. This could include the other services, DOD agencies, other government organizations such as the National Institute of Standards and Technology, and selected universities. It is critical that the Army obtain a clear and complete understanding of the vulnerabilities of each new software product, or generation of software, that will be used in the battlefield, and it may be infeasible for the Army (let alone SLAD and CECOM) to accomplish this by itself.

While it may seem that the use of COTS systems means that more people will know where the flaws are, it also means that vastly more people will be busy looking for those flaws and bringing their skills to the task of fixing them. Large organizations are often tempted to "roll their own" systems because "their needs are different" and because they can, they believe, achieve greater efficiency by dropping those system requirements that they do not need (at least at the time of design). This is not only false economy—the design costs are such that the organization is soon stuck with an out-of-date design that runs only on out-of-date hardware because of the rate of change of the field—but it is also an invitation to security disasters. There are, of course, exceptions: the Army will likely have to develop some Army-specific networked equipment (the sensor network is one obvious example), and the Army will be operating in modes that are different from fixed-base, civilian modes.

INFORMATION ASSURANCE

The challenge of information threat analysis and information assurance more generally was raised in the 1999-2000 report, and it continues to be a challenge. The Army faces two types of challenge in this arena: the security of its installed computer infrastructure based on extant (generally COTS) equipment, and the security of the special-purpose products that it is developing for field use in the future. The Board imagines that the planned Army Tactical Internet could be susceptible to new categories of attack, such as being invaded by software that does not present overt evidence of its presence. Troops that depend on information dominance for their effectiveness and safety might never know that their system had been compromised.

It is important to realize that computer and communication (C&C) systems are so complex that it is highly unlikely that a system could be designed that does not contain security flaws. Thus, it must be accepted that providing security is an ongoing operation, not something that can be built in with 100 percent certainty. Hence in the initial design, not only must great attention be paid to achieving a high initial level of security, but also to the issue of locating and correcting flaws during the life span of the system. It is also important to realize that a C&C system is not a static design, but one that typically evolves as new/changed functionality is introduced. The changes often introduce new security flaws.

Thus, security issues should be a fundamental aspect of many of the projects in CISD and some in SEDD—they should not be left for the communications or systems engineers to solve. For example, the agent framework architecture being developed within CISD should include security/assurance as a fundamental aspect. It is encouraging to note that information assurance in networks is an explicit topic within the telecommunications CTA, although the Board has not yet reviewed that consortium's work to evaluate whether the effort is adequate. It is very important to encourage cross-directorate work in areas like this one, in which, for example, CISD, SLAD, and SEDD can all bring valuable skills to the table. Information assurance may be an area in which greater in-house involvement with ARO programs could be fruitful, as well. There is a need for cross-directorate collaboration in this neglected area. In particular, the Board recommends that HRED and SLAD collaborate in some analysis and assessment activities that rely heavily on the performance of both humans and equipment.

MANAGEMENT AND WORKFORCE

There continues to be a need at ARL to address management and workforce issues. In the Board's 1999-2000 report, the "hiring of new people and the replacement of departing experts"[2] was raised as a key issue. ARL has clearly paid attention to the problems noted in that report related to staffing and has pursued some of the steps recommended there:

- High-quality in-house education programs;
- Off-site opportunities for internal staff to earn Ph.D.'s;

[2]NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory,* p. 20.

- Intergovernmental Personnel Act (IPA) loan assignments, fellowships, and work/study programs;
- Recruiting from Federated Laboratories university partners; and
- Inviting retirement-eligible staff to prepare monographs capturing their extensive experience for the benefit of future generations.

However, some challenges remain. One of the concerns of the Board involves the continuing problems with the recruitment and hiring of staff. The Board has found that CISD's growth is constrained not by financial resources, but by the directorate's ability to hire Ph.D.-level personnel, particularly in the area of networks, network protocols, and security. In the short term, CISD may need to find ways to backfill with consultants and/or visitors in certain crucial R&D areas. Another sort of recruitment problem is found in WMRD, in which over 40 percent of the managers are working in an acting, or temporary, capacity. The Board realizes that filling such higher-level slots is a slow process throughout government, but the constraints on WMRD's ability to fill division director slots in a timely manner places it at a serious disadvantage in competing for first-rate people. These workforce challenges seriously limit the ability of ARL to meet its goals for technical innovation and for timely development of state-of-the-art technology and its integration into major Army programs. For instance, the Board is concerned that a directorate with too many "acting" managers will not be able to effectively lead, innovate, and meld the technical challenges of the directorate. The directorate heads need to have the authority, to the extent possible within the government's personnel constraints, to fill these slots with people whose capabilities they trust.

The hiring of a new Ph.D., or a Ph.D. scientist with a year or more of postdoctoral experience, is the fastest and most cost-effective way for ARL to gain expertise in a new field. Currently the Board is told that, owing to the administrative process, it takes 4 to 5 months for ARL to make a direct hire at the DB-IV level (GS 14 and 15). A direct hire at the DB-V level (typical for division directors) requires 1 year. Such delays place ARL at a competitive disadvantage compared with industrial or academic employers. The Board understands that these delays are beyond the control of ARL, but it urges action toward reducing them. At the least, the Board recommends that the ARL director be given delegated hiring authority for the DB-IV level; this is essential in order to allow for timely recruitment at that level. The Board also hopes that some procedures can be put in place to reduce to 6 months or less the time required for ARL to make a hire at the DB-V level.

In addition to direct hiring, the Board recommends that ARL pursue the conversion of postdoctoral positions to career positions as another means of faster hiring. ARL may also be able to take greater advantage of its ARO and CTA contacts for recruitment. Most, if not all, ARL units have utilized an accelerated hiring process that is available for junior-level staff with a university grade point average of 3.5 or higher. ARL is to be commended for taking a proactive stance on recruiting S&Es from underrepresented minority groups and for enabling their professional development.

A final management issue to be mentioned is that, in addition to the pressures of increasing customer demands as ARL strengthens its ties and its usefulness to other Army and DOD organizations, there are always the management challenges associated with the continuing, exponential growth of technology. No R&D organization can afford to be static, concentrating only on those projects already under way. New, exploratory directions must be introduced and their potential assessed, and new strategic opportunities (e.g., the power and energy needs of the FCS) appear, calling on the capabilities of the organization and demanding either additional resources or the termination of "less promising" projects. ARL management, like R&D managers everywhere, must continually rebalance their programs and move resources from less-promising directions to new challenges.

COMPUTATIONAL MODELING

In its 1999-2000 report, the Board wrote that "ARL should ensure that models, simulations, and computer codes are being evaluated to define their scope of applicability and that they are updated, validated, and revised in order to provide the most reliable and timely answers to practical questions."[3] In the intervening 2 years, the Board's panels have observed additional cases in which models and computer codes are used with limited or no validation. The level of sophistication with the use of computational modeling varies widely across ARL. Many of the physical scientists (e.g., in WMRD and SEDD) are very conscious of the capabilities and limitations of modeling vis-à-vis experiment, and they ask themselves appropriate questions about how to validate their models and interpret the computational results. In some other units, computation is performed without explicitly asking these questions.

ARL should ensure that (1) models, simulations, and computer codes are being properly verified (i.e., the model's equations are coded correctly) and used; and (2) the results obtained with these codes are properly validated against appropriate analytical models and experimental data. Models—both analytical and those contained within computer codes—must be validated and verified against appropriate data in order to provide reliable and meaningful results to important practical questions. The panels have observed that many of the directorates continue to use models and computer codes without validation or in contexts that go beyond those for which they have been validated. These models and codes are used to simulate or predict the behavior of materials, weapons, ammunition, and soldiers. Often, the Board's panels have been told that the codes have been "validated" against other codes, but panel questions about the foundations and validation reveal that—

- No such validation exists;
- The validation was available for only a (small) portion of the model and code being developed;
- The model or code was being applied in regimes other than those in which they were either developed or verified; or
- Incorrect physical principles and laws were being applied in the modeling.

The use of models and computer codes that have not been properly grounded in the best available modeling or validated and verified by experimental data will almost surely lead to erroneous, costly, and dangerous predictions.

Ensuring the use of grounded models and validated/verified codes for both physical and human performance models is essential to the performance of ARL and to its credibility. ARL managers should consider a systematic initiative to provide the following:

- A cultural devotion to the importance of good modeling;
- A cultural pride in the importance of good computation practice;
- An ARL "gold standard" for both modeling and computation;
- The resources required to ensure that the appropriate level of computing is applied to the problem at hand;
- The experimental facilities needed to provide data and experience when no such data are available in the scientific and engineering literature; and
- A culture of mentoring by both senior scientists and middle-level managers that is devoted to developing and enhancing good habits of modeling and computing among junior scientists and engineers or among colleagues who are still learning how best to execute and interpret computational simulations. The return on such an investment in the culture and performance of ARL cannot be overstated.

[3]NRC, 2000, *1999-2000 Assessment of the Army Research Laboratory*, p. 21.

One needs to be extremely careful in pursuing "virtual experiments." Virtual experiments have the best chance of success if all relevant physics is understood and properly modeled. Without experimentation, though, no new physical phenomena are truly discovered—the virtual experiments can only suggest real behaviors. Virtual experiments are also incapable of providing detailed extensions of physical experiments. As a general rule, no basic research program should be without complementary experimental and analytical (numerical) parts.

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 of, and define the limits of the models being developed and used. For example, only a few portions of the IMPRINT maintenance model have been validated, and the workload analysis component of the model should be improved to produce more meaningful cognitive measures. Also, while the logistical force design model has been nicely applied to examine the efficiency of various approaches to maintaining the biological suite unit, results must be interpreted in light of the workings and limitations of the model, avoiding the temptation to take as gospel the numerical outputs of the model. Model developers and users at HRED need to recognize that a principal value of models is their assistance in structuring the thinking about processes, and that this value can be independent of the numerical results produced. For example, models can help to identify problems that might occur (such as at the extremes of normal operations) and to focus research efforts on these problems. As the use of modeling continues to grow, HRED should consider addressing the fertile area of human-model interaction (that is, the study and optimization of the ways in which human users interact with models).

In CISD, the Board's panel saw improvement in the quality of research being pursued, with increasing attention to the validation and verification of the models and codes (in particular for the high-performance computing presentations). However, it continues to be important to quantify, as accurately as possible, how the simulation results compare to the physical realities in order to determine how much trust to put in simulation outputs. Thus, additional effort should be put into validation, verification, and, especially, estimation of uncertainty.

6

Looking Forward

The Technical Assessment Board has seen continual improvement in ARL since it began assessing the laboratory in 1996. As fellow scientists and engineers, and as fellow citizens, Board members are very gratified to see this progress. It is especially noteworthy to see ARL contributing increasingly to the Army's vital R&D and to current and future Army technology. The Army's contributions to national security are impressive, and ARL's role in that effort is equally striking.

In the future, the Board will continue to work with ARL to improve the value of these external assessments.

Appendixes

Appendix A

Army Research Laboratory Organization Chart and Resources

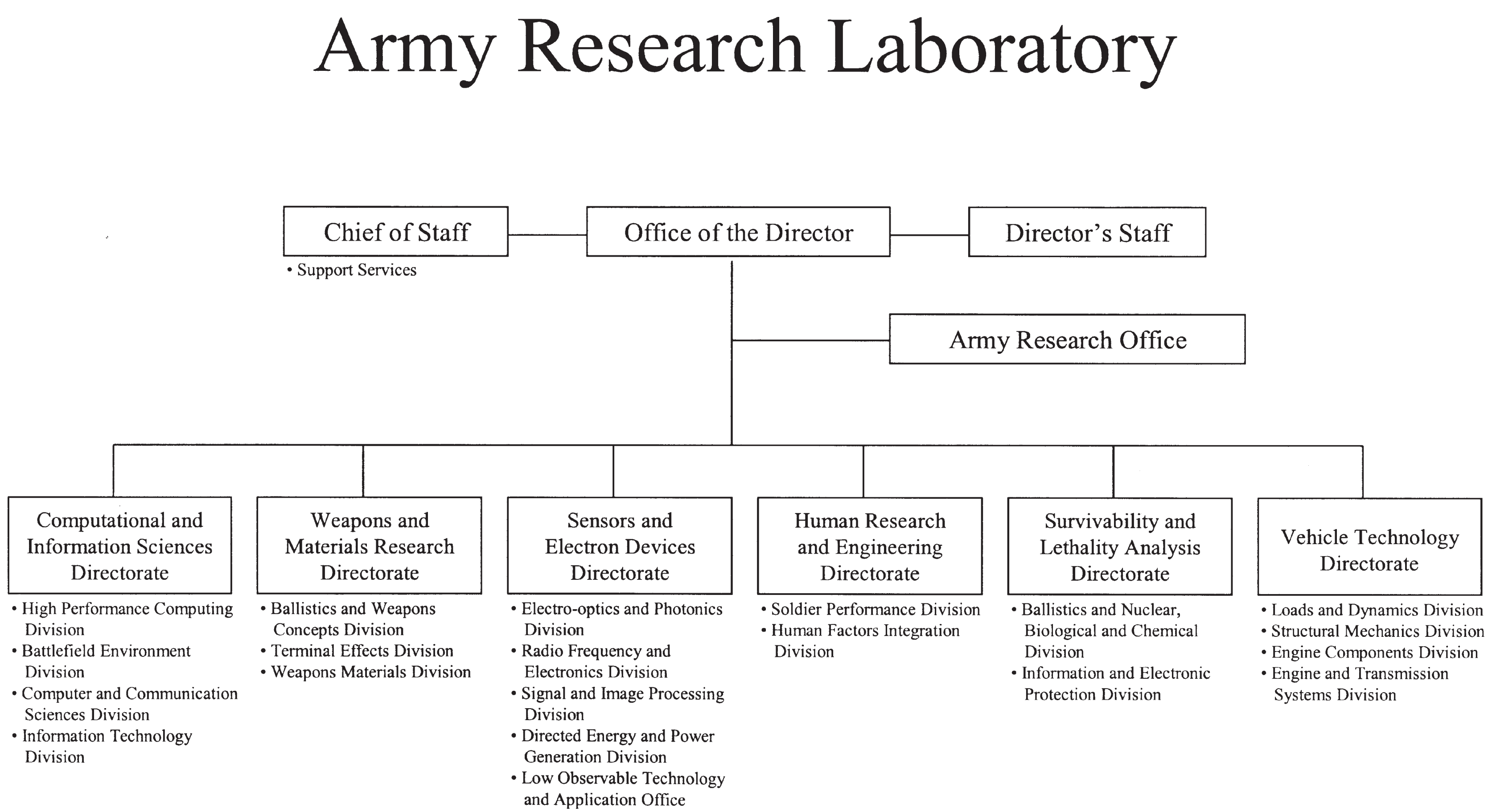
Army Research Laboratory
Chief of Staff
• Support Services
Office of the Director
Director's Staff
Army Research Office
Computational and Information Sciences Directorate
• High Performance Computing Division
• Battlefield Environment Division
• Computer and Communication Sciences Division
• Information Technology Division
Weapons and Materials Research Directorate
• Ballistics and Weapons Concepts Division
• Terminal Effects Division
• Weapons Materials Division
Sensors and Electron Devices Directorate
• Electro-optics and Photonics Division
• Radio Frequency and Electronics Division
• Signal and Image Processing Division
• Directed Energy and Power Generation Division
• Low Observable Technology and Application Office
Human Research and Engineering Directorate
• Soldier Performance Division
• Human Factors Integration Division
Survivability and Lethality Analysis Directorate
• Ballistics and Nuclear, Biological and Chemical Division
• Information and Electronic Protection Division
Vehicle Technology Directorate
• Loads and Dynamics Division
• Structural Mechanics Division
• Engine Components Division
• Engine and Transmission Systems Division

TABLE A.1 Resources: Army Research Laboratory Funding by Technical Unit, FY01 and FY02 (millions of dollars)

		Technical Unit								
Type of Funding	FY	ARO	CISD	HRED	SEDD	SLAD	VTD	WMRD	Mgt Spt	TOTAL
6.1	FY01	59.2	14.7	2.5	11.2		4.0	17.7	0.3	109.6
	FY02	76.4	15.7	2.6	11.7		4.1	16.4	0.5	127.4
6.1[a]	FY01		15.1		9.6					24.7
	FY02		7.4	5.6	11.2			2.2		26.4
6.2	FY01	0.1	17.2	17.9	47.1	6.8	4.3	74.2		167.6
	FY02		17.5	18.7	57.6	7.1	4.3	64.3	3.2	172.7
6.2[b]	FY01							2.0		2.0
	FY02							8.0		8.0
6.3/6.4/6.7	FY01				0.6			10.8		11.4
	FY02							15.3		15.3
6.6[c]	FY01	19.7		0.1		38.3		0.3	21.1	79.5
	FY02	12.6		1.0		33.7			27.4	74.7
6.6[d]	FY01		2.4	0.2					8.3	10.9
	FY02		2.3	0.2					3.0	5.5
Customer Reimbursement[e]	FY01	0.6		6.1	12.7	13.9	2.5	29.7	0.9	66.4
	FY02	1.0	13.3	6.1	16.6	11.6	4.0	39.3	1.0	92.9
Customer Direct Citation[f]	FY01	40.2	6.8	5.7	6.8	6.5		6.3		72.3
	FY02	45.0	3.1	19.4	4.6	4.8		6.5		83.4
OMA[g]	FY01	0.6	10.3					0.3	29.9	41.1
	FY02	0.5	9.0					0.5	32.4	42.4
OSD[h]	FY01	90.9	2.0		0.4			0.6		93.9
	FY02	93.5						1.0		94.5
DARPA[i]	FY01	71.1	3.0		50.4			0.9		125.4
	FY02	77.9	1.5	0.1	45.9			0.4		125.8
MSRC/HPC[j]	FY01		69.4							69.4
	FY02		95.8							95.8
Total	FY01	282.4	140.9	32.5	138.8	65.5	10.8	142.8	60.5	874.2
	FY02	306.9	165.6	53.7	147.6	57.2	12.4	153.9	67.5	964.8

[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 of 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

Appendix B

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

Army Research Laboratory Technical Assessment Board and Panels, 2002

ARL Technical Assessment Board

C. William Gear, chair
George E. Dieter
Michael G. Dunn
Clive L. Dym
David R. Ferguson
Arthur Guenther
Frank A. Horrigan
Mary Jane Irwin
Keith H. Jackson
Christine M. Mitchell
James W. Mitchell
Richard W. Pew

Armor and Armaments Panel

(reviews WMRD)

George E. Dieter, chair*
Charles E. Anderson, Jr.
Melvin R. Baer
Rodney J. Clifton
Phillip Colella
Dennis E. Grady
Charles L. Mader
James E. McGrath
James W. Mitchell*
Joseph E. Shepherd
Kenneth S. Vecchio
Sheldon Wiederhorn

Air and Ground Vehicle Technology Panel

(reviews VTD)

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Roy Battles
Clive L. Dym*
Charbel H. Farhat
Jacob Fish
Awatef Hamed
Wesley L. Harris
S. Michael Hudson
Wolfgang G. Knauss
Francis W. Zok

Soldier Systems Panel

(reviews HRED)

Richard W. Pew, chair*
Dennis G. Faust
Douglas H. Harris
Robert T. Hennessy
Robert A. Henning
Bonnie Elizabeth John
Kenneth R. Laughery
John D. Lee
Christine M. Mitchell*
D. Alfred Owens

Digitization and Communications Science Panel

(reviews CISD)

Mary Jane Irwin, chair*
Jack Dongarra
Brant Foote
C. William Gear*
Bruce B. Hicks
Leslie P. Kaelbling
Eugenia Kalnay
Mitchell P. Marcus
Laurence B. Milstein
Gary J. Minden
Charles E. Perkins
Dennis W. Thomson

Sensors and Electron Devices Panel

(reviews SEDD)

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Henry E. Bass
Elton J. Cairns
L. Richard Carley
Arthur Guenther*
George I. Haddad
Alfred O. Hero
Narain G. Hingorani
Keith H. Jackson*
Timothy N. Krabach
Karen W. Markus
David C. Munson, Jr.
John F. Schultz
Fritz Steudel

Survivability and Lethality Analysis Panel

(reviews SLAD)

David R. Ferguson, chair*
Romesh C. Batra
John D. Christie
Stephen D. Crocker
Arthur Guenther*
Daniel N. Held
Melvin F. Kanninen
Richard Lloyd
Teresa F. Lunt
John McHugh
Max D. Morris
John Reese
John F. Schultz
John C. Sommerer

* ARLTAB Member.

BIOGRAPHICAL SKETCHES

Army Research Laboratory Technical Assessment Board

C. WILLIAM GEAR, *chair*, is president emeritus of the NEC Research Institute. Prior to joining NEC, he was head of the Department of Computer Science and professor of computer science and applied mathematics at the University of Illinois at Urbana-Champaign. His research expertise is in numerical analysis and computational software. Dr. Gear is a member of the National Academy of Engineering (NAE) and a fellow of the American Academy of Arts and Sciences, the Institute of Electrical and Electronics Engineers (IEEE), the American Association for the Advancement of Science (AAAS), and the Association for Computing Machinery (ACM). He served as president of the Society for Industrial and Applied Mathematics (SIAM) and was the recipient of the ACM SIGNUM George E. Forsythe Memorial Award and Fulbright and Johnson Foundation fellowships.

GEORGE E. DIETER is Glenn L. Martin Institute Professor of Engineering at the University of Maryland, and formerly served as dean of engineering there 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. In his earlier 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. Dr. Dieter received his D.Sc. degree from Carnegie Mellon University, and he is a fellow of ASM International (the society for materials engineers and scientists), the Minerals, Metals, and Materials Society (TMS), the 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 ASEE. In addition, he has been chair of the Engineering Deans Council and president of 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.*

MICHAEL G. DUNN has more than 35 years of industry experience at the Lockheed Missiles and Space Company and Calspan Corporation (formerly the Cornell Aerospace Laboratory). He moved to the Ohio State University in 1995, 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. engine manufacturers as well as those of NASA, Wright-Patterson Air Force Base, and the Defense Nuclear Agency. He is the author or coauthor of more than 150 reports and archival publications. Dr. Dunn has pioneered the use of short-duration experimental techniques to obtain fundamental measurements at design-corrected conditions for a host of full-stage rotating turbines.

CLIVE L. DYM is Fletcher Jones Professor of Engineering Design and director of the Center for Design Education at Harvey Mudd College. Dr. Dym's primary interests are in engineering design and structural mechanics. Previously, he held appointments at the University of Massachusetts at Amherst (1977-1991); Bolt, Beranek and Newman (1974-1977); Carnegie Mellon University (1970-1974); Institute for Defense Analyses (1969-1970); and the State University of New York at Buffalo (1966-1969). Dr. Dym was also head of his department at the University of Massachusetts (1977-1985) and chaired his department at Harvey Mudd (1999-2002). Dr. Dym has held visiting appointments at the TECHNION-Israel Institute of Technology (1971), the Institute for Sound and Vibration Research at the University of Southampton (1973), Stanford University and Xerox PARC (1983-1984), Carnegie Mellon (1990), and as Eshbach Visiting Professor of Civil Engineering at Northwestern University (1997-1998). Dr. Dym has authored or coauthored 10 books, more than 100 archival publications and technical reports, is an active consultant to industry, and was founding editor of the journal *Artificial Intelligence for Engineering Design, Analysis, and Manufacturing*.

DAVID R. FERGUSON is Boeing Information and Support Services' senior geometry technical fellow and has lead responsibility for geometry research and development at Boeing. His work at Boeing has involved the application of mathematics to a wide variety of real-world engineering problems. In particular, he has worked extensively on issues related to computer-aided geometric design and in the specific area of developing mathematical algorithms for curve and surface generation. He has written and talked 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 SIAM and is an editor for two professional journals.

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, and the International Society for Optical Engineers (SPIE), at which he is a member of the board of directors. 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 on Optics and a member of the Russian Academy of Sciences (Ural Division).

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 35 years of experience in advanced electronics, electro-optics, and computer systems. He has a wide general knowledge of all technologies relevant to military systems, and extensive experience in planning and managing independent R&D investments and in projecting future technology growth directions. Dr. Horrigan is a member of the American Physical Society (APS) and the AAAS, and he also serves on the National Research Council's (NRC's) Naval Studies Board. He holds a Ph.D. in theoretical physics from Harvard University.

MARY JANE IRWIN is a distinguished professor 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. For her research contributions, Dr. Irwin was named fellow of the IEEE in 1995 and fellow of the ACM in 1996. She received the Penn State Engineering Society's Premier Research Award in 2001. Dr. Irwin is currently serving as chair of the National Science Foundation's Computer Information Sciences and Engineering Directorate's Advisory Committee, as editor-in-chief of ACM's *Transactions on Design Automation of Electronic Systems,* and as an elected member of the Computing Research Association's board of directors. She received her Ph.D. in computer science from the University of Illinois at Urbana-Champaign.

KEITH H. JACKSON is the associate director for 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.

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JAMES W. MITCHELL is the director of Materials Processing Research at Bell Laboratories, Lucent Technologies. Dr. Mitchell is a member of the NAE. He is a former member the NRC's Commission on Physical Sciences, Mathematics, and Applications and Board on Chemical Sciences and Technology. Dr. Mitchell received his Ph.D. in analytical chemistry from Iowa State University.

RICHARD W. PEW is a principal scientist at the BBN Technologies unit of Verizon. He holds a bachelor's degree in electrical engineering from Cornell and a Ph.D. in psychology from the University of Michigan. Dr. Pew has 35 years of experience in human factors, human performance, and experimental psychology as they relate to systems design and development. He spent 11 years on the faculty of the Psychology Department at Michigan, where he was involved in human performance teaching, research, and consulting before moving to BBN in 1974. Dr. Pew was the first chair of the NRC Committee on Human Factors; he has been president of the Human Factors Society and president of Division 21 of the American Psychological Association, the division concerned with engineering psychology. He has also been chair of the Biosciences Panel of the Air Force Scientific Advisory Board. He recently chaired an NRC panel that produced the book *Modeling Human and Organizational Behavior*. Dr. Pew has more than 60 publications as book chapters, articles, and technical reports.

Staff

SCOTT T. WEIDMAN is the director of the ARL Technical Assessment Board, director of the NRC's Board on Assessment of NIST Programs, and director of the NRC's Board on Mathematical Sciences and Their Applications. He joined the NRC in 1989 with the Board on Mathematical Sciences and moved to the Board on Chemical Sciences and Technology in 1992. At the NRC he has staffed studies on a wide variety of topics related to mathematical, chemical, and materials sciences, laboratory assessment, and science and technology policy. After receiving bachelor of science degrees in mathematics and materials science from Northwestern University in 1977, Dr. Weidman worked for General Electric Corporation and General Accident Insurance Company before earning M.S. and Ph.D. degrees in applied mathematics at the University of Virginia. After a postdoctoral year with Exxon Research and Engineering, Dr. Weidman joined the consulting firm MRJ, Inc., and performed research in parallel computing applied to operations research, image analysis, and air pollution modeling. He is a member of SIAM, Sigma Xi, and IEEE.

CY L. BUTNER is a senior program officer with the ARL Technical Assessment Board. Shortly after joining the NRC in 1997, he moved from the Aeronautics and Space Engineering Board to his current appointment. Before joining the NRC, Mr. Butner served as an independent consultant to the Aeronautics and Space Engineering Board for 2 years, during which time he supported an ongoing peer review process for the Air Force Office of Scientific Research proposals and 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 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 co-op 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.

DAWN M. COURTNEY is a senior project assistant and financial associate with the ARL Technical Assessment Board. Before joining the NRC in 1998, she was a faculty secretary with Mount Vernon College/George Washington University (where she managed the Office of Faculty Services), an executive assistant with Graham Staffing, and a project coordinator with the American Psychiatric Association. Her earlier experience included positions with the Vietnam Women's Memorial Project, the Gadsden County School District, and the Federal Emergency Management Agency. Ms. Courtney is a member of the National Association for Female Executives and holds a B.A. degree in political science from Howard University.

JAMES P. McGEE is a study director and senior research associate at the NRC. In 1994, Dr. McGee joined the Division on Education, Labor, and Human Performance of the NRC's Commission on Behavioral and Social Sciences and Education. Dr. McGee directs the Soldier Systems Panel of the ARL Technical Assessment Board. He also supports National Academies panels and committees in the areas of applied psychology (e.g., the current committee on musculoskeletal disorders and the workplace and earlier committees on air traffic control automation and the changing nature of work) and education (e.g., the committee on educational interventions for children with autism). Prior to joining the NRC, Dr. McGee held scientific, technical, and management positions in human factors psychology at IBM, RCA, General Electric, General Dynamics, and United Technologies corporations. He has also instructed courses in applied psychology at several colleges. A graduate of Princeton University and Fordham University, Dr. McGee is a member of the Potomac Chapter of HFES.

Air and Ground Vehicle Technology Panel

MICHAEL G. DUNN (see Board sketches, above)

ROY BATTLES is vice president of Aircraft Systems 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.

CLIVE L. DYM (see Board sketches, above)

CHARBEL H. FARHAT is chair of the Department of Aerospace Engineering Sciences and director of the Center for Aerospace Structures at the University of Colorado at Boulder. Dr. Farhat is also a professor in the Department of Aerospace Engineering Sciences, the Center for Aerospace Structures, and the Center for Applied Parallel Processing at the university. 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, and 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 U.S. Association for Computational Mechanics and the American Institute of Aeronautics and Astronautics (AIAA). He also is a member of SIAM and ASME. 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 U.S. Association for Computational Mechanics and the International Association for Computational Mechanics. Dr. Fish is consultant to the NY Department of Law, General Electric Corporate Research and Development, Lockheed Missiles and Space Company, 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 American Society for Engineering Education (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.

WESLEY L. HARRIS is the Charles Stark Draper Professor of Aeronautics and Astronautics and director of the Lean Sustainment Initiative at the Massachusetts Institute of Technology (MIT). Dr.

Harris is a member of the NAE. He has a broad background in aerospace engineering and computational fluid dynamics and has performed research in such areas as theoretical and experimental unsteady aerodynamics and aeroacoustics, shock structure in gas mixtures, quasi-linear techniques applied to aerodynamic noise analysis, helicopter rotor acoustics, and hypersonic and transonic flow analyses. In addition to his distinguished career as an educator and researcher, he also has served as associate administrator for aeronautics at NASA Headquarters. Dr. Harris is a fellow of the AIAA and of the American Helicopter Society. He is also a member of the APS, SIAM, Sigma Xi, AAAS, and ASEE. He received his Ph.D. in aerospace engineering from Princeton University.

S. MICHAEL HUDSON retired in 2001 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 also has served as a member of two aeronautics committees of the NRC's Aeronautics and Space Engineering Board.

WOLFGANG G. KNAUSS, von Kàrmàn Professor of Aeronautics and Applied Mechanics at the California Institute of Technology, has been on the faculty there since 1965. His work is devoted to understanding the mechanics of time-dependent fracture in polymeric materials to enable prediction of the long-term failure of structures made from polymeric and other time-dependent materials. Dr. Knauss also has been a visiting professor at several distinguished foreign universities and a consultant to many companies. He is a member of the NAE, a foreign member of the Russian Academy of Natural Sciences, a corresponding member of the International (Russian) Academy of Engineering, and chair of the U.S. National Committee of Theoretical and Applied Mechanics. He is a recipient of the Kapitsa Medal from the Russian Academy of Natural Sciences, the Murray Medal and Lazan Award from the Society of Experimental Mechanics, the Koiter Medal from the ASME, and was awarded a senior scientist fellowship by the A. von Humboldt Foundation of the German government. Dr. Knauss holds a Ph.D. from the California Institute of Technology and is a fellow of the ASME, the Society for Experimental Mechanics, the American Academy of Mechanics, and the Institute for the Advancement of Engineering. He also has current and past affiliations with a number of additional societies, committees, and professional publications.

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 (see Board sketches, above)

CHARLES E. ANDERSON, JR., is director of the Engineering Dynamics Department of the Mechanical and Materials Engineering Division of Southwest Research Institute. He is an expert in penetration mechanics and hypervelocity impacts. 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, he is a senior institute fellow of the Institute for Advanced Technology, and he is on the editorial advisory board of *International Journal of Impact Engineering*. Dr. Anderson received his Ph.D. in physics from Rensselaer Polytechnic Institute.

MELVIN R. BAER is a senior scientist in engineering sciences at 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) group, the U.S. Navy reinvestigation of the USS *Iowa* incident, and the National Transportation Safety Board investigation of the TWA 800 accident. Dr. Baer received his Ph.D. in mechanical engineering from Colorado State University.

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 and dynamic fracture, mechanics of hydraulic fracturing, and numerical methods. In addition to his work at Brown University, Dr. Clifton also has held a number of positions, including positions at Stanford University, Brookhaven National Laboratory, and Sandia National Laboratories. He is a fellow of the American Academy of Mechanics and a member of the ASME, APS, and American Society of Civil Engineers. Dr. Clifton received his Ph.D. in civil engineering from Carnegie Mellon University.

PHILLIP COLELLA is group leader of the Applied Numerical Algorithms Group at the National Energy Research Scientific Computing Center at Lawrence Berkeley National Laboratory. His expertise is in numerical methods for partial differential equations and their application to science and engineering problems. He received the IEEE Computer Society's 1998 Sidney Fernbach Award for fundamental contributions in the development of software methodologies used to solve numerical partial differential equations, and their application to substantially expand our understanding of shock physics and other fluid dynamics problems.

LORRAINE F. FRANCIS (panel member in 2001) is a professor in the Department of Chemical Engineering and Materials Science at the University of Minnesota. A recipient of a National Science Foundation (NSF) Young Investigator Award, her expertise is in ceramic and polymer coating fundamentals and ceramic coatings and composites for electronic and dental applications. Dr. Francis is a member of the American Ceramic Society, Materials Research Society, ASM International, American Association for Dental Research, Sigma Xi, and Phi Kappa Phi. She holds a Ph.D. in ceramic engineering from the University of Illinois.

JAMES GLIMM (panel chair and Board member in 2001) is chair of the Department of Applied Mathematics and Statistics at the State University of New York at Stony Brook and director of the Center for Data Intensive Computing at Brookhaven National Laboratory. He previously held faculty positions at New York University, Rockefeller University, and MIT. He is a member of the National Academy of Sciences (NAS) and a recipient of the Steele prize of the AMS and the Dannie Heinemann prize of the APS. His research interests include computation and modeling for turbulent and chaotic flows, mathematical theory of conservation laws, stochastic methods, modeling of elastic-plastic deformation, and the application of mathematical methods to industrial problems.

DENNIS E. GRADY 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.

ARTHUR GUENTHER (panel member in 2001; see Board sketches, above)

CHARLES L. MADER, an independent consultant, is president of Mader Consulting Company and a fellow emeritus of the Los Alamos National Laboratory (LANL). He continues to work part time at the LANL as a retired fellow. His specialty is physical chemistry, and he has extensive expertise in explosives, thermodynamics, hydrodynamics, equation of state, numerical modeling of detonation chemistry and physics, and chemically reactive fluid dynamics. Dr. Mader worked at the LANL for more than 30 years before establishing his consulting firm in 1987. He is a fellow of the American Institute of Chemists and a member of the American Chemical Society (ACS), the APS, the Combustion Institute, Sigma Xi, and the Marine Technology Society. Dr. Mader received his Ph.D. from Pacific Western University.

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, 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 NSF'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.

JAMES W. MITCHELL (see Board sketches, above)

JOSEPH E. SHEPHERD is a professor of aeronautics at the California Institute of Technology (Caltech) and head of its Explosion Dynamics Laboratory. His research interests are in the fields of combustion, propulsion, and explosions—in particular, ignition and propagation of flames, transition from flames to detonation, propagation of detonations and shock waves, response of structures to explosions, application of detailed chemistry to combustion modeling, and advanced computational methods for the simulation of high-explosive detonation. Professor Shepherd holds a Ph.D. in applied physics from Caltech and was a member of the technical staff at Sandia National Laboratories and a faculty member at Rensselaer Polytechnic Institute prior to joining the Caltech faculty.

KENNETH S. VECCHIO is a professor of materials science and engineering in the Department of Mechanical and Aerospace Engineering at the University of California, 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 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.

SHELDON WIEDERHORN is a senior NIST fellow in the Materials Science and Engineering Laboratory of the National Institute of Standards and Technology. With 39 years of experience at NIST (formerly the National Bureau of Standards) and 3 years at DuPont 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 in 1995. Dr. Wiederhorn holds a Ph.D. in chemical engineering from the University of Illinois.

Digitization and Communications Science Panel

MARY JANE IRWIN (see Board sketches, above)

JACK DONGARRA is University Distinguished Professor of Computer Science in the Department of Computer Science at the University of Tennessee, Knoxville and an adjunct R&D participant in the Computer Science and Mathematics Division at Oak Ridge National Laboratory. He also is a member of the NAE and serves as 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. Dr. Dongarra received his Ph.D. in applied mathematics from the University of New Mexico.

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, and his specialties are severe local storms and cloud physics. Since coming to 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.

C. WILLIAM GEAR (see Board sketches, above)

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, he 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 Argonne National Laboratory. Earlier, Mr. Hicks 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 is a member of the Royal Meteorological Society, the American Meteorological Society, and the American Geophysical Union.

LESLIE P. KAELBLING 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 has written numerous papers, five book chapters, and one book, and she was the editor for 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.

EUGENIA KALNAY, an NAE member, is a Distinguished University Professor of Meteorology at the University of Maryland. She has expertise in ensemble forecasting, numerical weather prediction, data assimilation, and coupled ocean-atmosphere modeling. Before joining the University of Maryland, for 11 years she was the director of the Environmental Modeling Center of the National Centers for Environmental Prediction of the National Weather Service. She is a fellow of the American Meteorological Society and has received a number of prestigious awards. She received her Ph.D. in meteorology from MIT.

MITCHELL P. MARCUS is a professor of artificial intelligence and chair of the Department of Computer and Information Science at the University of Pennsylvania. His expertise is in artificial intelligence, with a primary focus on natural language applications. In addition, Dr. Marcus holds an appointment in linguistics at the University of Pennsylvania. He also is the principal investigator for the Penn Treebank Project and is a member of the External Advisory Committee of the Center for the Study of Language and Information at Stanford University. He serves on many program committees for the

Association for Computational Linguistics, the American Association for Artificial Intelligence, and the Defense Advanced Research Projects Agency (DARPA). Previously, he worked for AT&T Bell Laboratories. Dr. Marcus holds a Ph.D. in electrical engineering and computer science from MIT.

LAURENCE B. MILSTEIN is a professor and former department chair in the Department of Electrical and Computer Engineering at the University of California at San Diego. He has been in the department since 1976, working in the area of digital communication theory with special emphasis on spread-spectrum communication systems. He also has been a consultant to both government and industry in radar and communications. Before joining his current department, Dr. Milstein was a member of the Department of Electrical and Systems Engineering at Rensselaer Polytechnic Institute and an employee of the Space and Communications Group of Hughes Aircraft Company. He is a fellow of the IEEE, a former member of the boards of governors of the IEEE Communications Society and of the IEEE Information Theory Society for three and two terms, respectively, and a former vice president for technical affairs for the IEEE Communications Society. Dr. Milstein holds a Ph.D. from the Polytechnic Institute of Brooklyn.

GARY J. MINDEN is a professor in the Department of Electrical Engineering and Computer Science at the University of Kansas. Dr. Minden led the implementation of the computer engineering degree program. His research interests are in large-scale distributed systems, which encompass high-performance networks, computing systems, and distributed software systems. Dr. Minden completed a tour at DARPA in 1996, where he was program manager for the Networking Systems and Active Networking programs. Dr. Minden is a member of the IEEE, ACM, Eta Kappa Nu, and Tau Beta Pi.

CHARLES E. PERKINS is a research fellow with the Nokia Research Center. He serves as document editor for the Mobile Internet Protocol (IP) working group of the Internet Engineering Task Force (IETF), is author or coauthor of standards-track documents in the Mobile IP, SVRLOC, Dynamic Host Configuration, and IP Next Generation Transition working groups of the IETF, and serves on the Internet Architecture Board. Mr. Perkins recently authored a book on Mobile IP and has published a number of papers in the areas of mobile networking, ad hoc networking, route optimization for mobile networking, resource discovery, and automatic configuration for mobile computers. He is associate editor for *Mobile Communications and Computing Review*, official publication of ACM SIGMOBILE, and area editor for the journals *Wireless Networks*, *Mobile Networking and Applications*, and *IEEE/ACM Transactions on Networking*, as well as for *IEEE Internet Computing* magazine.

LAWRENCE SNYDER (Board and panel member in 2001) is a professor of computer science and engineering at the University of Washington. He joined the faculty in 1983 after having served on the faculties of Yale and Purdue Universities. He has had visiting faculty appointments at Harvard, MIT, the University of Sydney, Eidgenössische Technische Hochschule Zürich, and Kyoto University. His research has ranged from proofs of undecidability to the design and development of a 32-bit single chip (CMOS) microprocessor. His chief research interest is parallel computation. He was principal investigator on the Chaos Network Routing Project and currently heads the ZPL Parallel Language Project. Professor Snyder chaired the NSF Advisory Committee for the Division of Computer Research. He chaired the NRC committee that issued the report *Academic Careers for Experimental Computer Scientists and Engineers* for the Computer Science and Telecommunications Board (CSTB) and chaired the NRC committee that issued *Being Fluent with Information Technology*, also for CSTB. He is on the board of directors of the Computer Research Association and is a fellow of the IEEE and the ACM.

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, 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 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, a number of DOD oversight and advisory committees, and extended service, both to Argonne National Laboratory and continuing at Lawrence Livermore National Laboratory. He is a multidegree graduate in physics and meteorology (Ph.D.) of the University of Wisconsin.

Sensors and Electron Devices Panel

FRANK A. HORRIGAN (see Board sketches, above)

HENRY E. BASS is 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, and his experience includes research in the fields of physical acoustics and molecular energy transfer in gasses. Since joining the physics faculty at the University of Mississippi in 1970, Dr. Bass has served in many positions at the university. 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.

ELTON J. CAIRNS is a professor of chemical engineering at the University of California at 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 with 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 of the Electrochemical Society and the American Institute of Chemists and a member of the American Institute of Chemical Engineers, 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 at Berkeley.

L. RICHARD CARLEY is a professor of electrical and computer engineering at Carnegie Mellon University (CMU). His expertise includes the design of analog circuits and systems for mixed-signal integrated circuits (ICs) and system-on-a-chip ICs, development of computer-aided design tools to support the analog IC design flow, and design of integrated microelectromechanical systems and control/sensing electronics for inertial sensing and IC-based mass data storage devices. While at CMU, Dr. Carley served as the associate director for electronic subsystems for the Data Storage Systems Center (1990-1999). He also has worked for MIT's Lincoln Laboratories and has been a consultant for numerous companies. In addition, he was a cofounder of NeoLinear, an analog design automation tool provider. Dr. Carley has been granted 10 patents, authored or coauthored more than 120 technical papers, and authored or coauthored 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. from MIT.

MARGARET A. FRERKING (panel member in 2001) is project manager at the Jet Propulsion Laboratory (JPL) for the Microwave Instrument for the Rosetta Orbiter (MIRO) program. She has more than 20 years of experience in observational and experimental astrophysics and Earth remote sensing, and her specialties include millimeter-wave and submillimeter-wave instrumentation for atmospheric and astrophysical research. Dr. Frerking has more than 12 years of experience in developing flight hardware, having served as the cognizant engineer for the millimeter-wave heterodyne receiving system for the Microwave Limb Sounder. She also served as lead technologist for the Submillimeter Astrophysics Mission Preproject at JPL and as technical task manager for NASA's Submillimeter Wave Sensors Program, and she is currently the project manager as well as co-investigator on the MIRO experiment. A member of the American Astronomical Society, Dr. Frerking holds a Ph.D. in physics from MIT.

ARTHUR GUENTHER (see Board sketches, above)

GEORGE I. HADDAD is the Robert J. Hiller Professor of Electrical Engineering and Computer Science at the University of Michigan. He served as chair of the department from 1975 to 1986 and 1991 to 1997. He also served as director of the Electron Physics Laboratory from 1969 to 1975, director of the Solid-State Electronics Laboratory from 1986 to 1991, and director of the Center for High Frequency Microelectronics from 1986 to 2000. His expertise is in the areas of microwave and millimeter-wave devices and integrated circuits, microwave-optical interactions, and optoelectronic devices and integrated circuits. Dr. Haddad served as editor of the *IEEE-Microwave Theory and Techniques Society (MTT-S) Transactions* from 1968 to 1971 and was on the MTT-S-Administrative Committee from 1970 to 1976. He received the MTT-S Distinguished Service Award and the 1996 MTT-S Distinguished Educator Award, along with other prestigious awards. He also has served on and participated in numerous other IEEE committees and activities. Dr. Haddad is a fellow of the IEEE and a member of the NAE, Eta Kappa Nu, Sigma Xi, Phi Kappa Phi, Tau Beta Pi, the American Society for Engineering Education, and the APS. He holds a Ph.D. in electrical engineering from the University of Michigan.

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 signal and image processing, statistical communication theory, detection and estimation theory, 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 Labs of the Ford Motor Company, Ecole Nationale des Techniques Avancées, Ecole Superieure d'Electricite, and MIT Lincoln Laboratory. In addition, throughout his career, Dr. Hero 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 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 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 (see Board sketches, above)

TIMOTHY N. KRABACH is program manager of the Life Detection Science and Technology Program Office at the Jet Propulsion Laboratory. 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 also serves as a member of the University of Illinois Physics Department external advisory board. Dr. Krabach received his Ph.D. in physics from the University of Illinois at Urbana-Champaign.

KAREN W. MARKUS is the vice president, Technology Strategy for JDS Uniphase, working on identification of next-generation technologies, mergers and acquisitions. She has been involved in semiconductor, microelectromechanical systems, and other wafer-based technologies for more than 18 years. Ms. Markus founded Cronos Integrated Microsystems, which was acquired by JDS Uniphase in 2000. She is a member of the board of Okmetic Oy, Silicon Bandwidth, and Scion Photonics, and is on the technical advisory board of ST Systems Corporation. She also served on the NRC Committee on Advanced Materials and Fabrication Methods for Microelectromechanical Systems.

DAVID C. MUNSON, JR., is a professor in the Department of Electrical and Computer Engineering, a research professor in the Coordinated Science Laboratory, and a part-time faculty member in the Beckman Institute for Advanced Science and Technology at the University of Illinois, 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, interferometry, and high-precision Global Positioning System (GPS). 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 and a member of Eta Kappa Nu and Tau Beta Pi. Among numerous honors and awards, he has received the Meritorious Service Award from the IEEE Signal Processing Society and an IEEE Third Millennium Medal. He has held leadership positions in the IEEE's Signal Processing Society and Circuits and Systems Society, served in a variety of other IEEE positions, and is currently serving on the editorial board of *The*

Proceedings of the IEEE and on the IEEE Kilby Signal Processing Medal Committee. Dr. Munson received his Ph.D. in electrical engineering from Princeton University.

MARSHALL I. NATHAN (panel member in 2001) holds the Centennial Chair at the University of Minnesota (Department of Electrical and Computer Engineering). An experimentalist, his expertise is in high-speed III-V semiconductor device physics, and his primary interest is in making semiconductor devices using molecular beam epitaxy to grow the semiconductor layers. Professor Nathan's research focuses on the study of phenomena and the measurement of parameters related to high-speed electronic and optoelectronic devices. He is a member of the NAE, a fellow of the APS and IEEE, and a recipient of the IEEE David Sarnoff Award and LEOS, IEEE recognition for the semiconductor laser. He received his Ph.D. in physics from Harvard University.

LOUIS L. SCHARF (panel member in 2001) is a professor of electrical and computer engineering and statistics at Colorado State University. He is a recognized expert in statistical signal processing, as it applies to adaptive radar, sonar, and wireless communication. His current interests are in rapidly-adaptive receiver design for space-time and frequency-time signal processing in the wireless communication channel. Professor Scharf has held faculty positions at the University of Rhode Island, Kingston, and the University of Colorado, Boulder. He has held visiting appointments at Ecole Superieure d'Electricite (Gif-sur-Yvette), Ecole Nationale Superieure des Telecommunications (Paris), EURECOM (Nice), University of La Plata, Argentina, and University of Wisconsin, Madison. Professor Scharf is a fellow of IEEE and past chair of the Fellow Committee for the IEEE Signal Processing Society. He serves on its Technical Committees for Theory and Methods and for Sensor Arrays and Multichannel Signal Processing. He has received numerous awards, including an IEEE Distinguished Lectureship, an IEEE Third Millennium Medal, and the Technical Achievement Award from the IEEE Signal Processing Society. He coauthored a 2001 paper that produced an IEEE Signal Processing Society Award for its first author as Best Paper by a Young Author. He received his Ph.D. from the University of Washington, Seattle.

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 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.

FRITZ STEUDEL is a consultant to and former employee of Raytheon. 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 BMDO GBR 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 in 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.

BARBARA A. WILSON (panel member in 2001) is chief technologist of the Air Force Research Laboratory. Previously, she was the director of the Center for Space Microelectronics Technology at JPL, and the laboratory's chief technologist. After earning her Ph.D. in physics from the University of Wisconsin-Madison, she worked in basic research at AT&T Bell Laboratories, with a focus on semiconductor heterostructures. At JPL, she has served as manager of the Microdevices Laboratory and as deputy manager of NASA's New Millennium flight validation program. Dr. Wilson is a fellow of the APS and a former member of its executive board. She is also a corresponding member of the International Academy of Astronautics. As a member of the Air Force Scientific Advisory Board (SAB), she participated in a number of U.S. Air Force studies, including the forward-looking New World Vistas Study, and has chaired the SAB review of the Air Force Office of Scientific Research.

Soldier Systems Panel

RICHARD W. PEW (see Board sketches, above)

JOHN F. BROCK (panel member in 2001) has more than 30 years of experience in human factors engineering, training, and computer science R&D. He is currently the director of training and simulation for the Milestone Group, where he manages key human performance improvement programs. Mr. Brock has managed programs in human factors engineering and training for InterScience America, Essex Corporation, Hay Systems, and Honeywell Corporation. He has performed contract research for a wide range of government and private agencies, including the U.S. Air Force, Army, and Navy, DARPA, NASA, the Departments of Defense and Justice, and the Honeywell and Lockheed Martin corporations. Mr. Brock is the author or coauthor of 4 book chapters on computer-based instruction and more than 90 publications and presentations. He is an adjunct professor at George Washington University and has taught at the University of Michigan, the Navy Postgraduate School, the MITRE Corporation, and George Mason University.

DENNIS G. FAUST is 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. State Department, 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 has served as a contributor to publications such as the John Wiley & Sons *Encyclopedia of Psychology*. Dr. Faust received his Ed.D. in counseling and educational psychology, with supporting fields in research and psychometrics, from the University of Virginia.

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 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.

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 AAAS.

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. 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 social psychophysiology. He currently serves as secretary-treasurer and president-elect of PIE, a technical group of the International Ergonomics Association. He is a board-certified professional ergonomist and former NRC/National Institute of Occupational Safety and Health (NIOSH) postdoctoral fellow at NIOSH.

BONNIE ELIZABETH JOHN is an associate professor in the Human-Computer Interaction Institute, School of Computer Science at 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.

KENNETH R. LAUGHERY is Herbert S. Autrey Professor of Psychology at Rice University, where he has conducted research and taught since 1984. His general areas of research and practice are cognitive psychology, applied psychology, and human factors and ergonomics. Dr. Laughery's recent research has focused on two areas: perception and knowledge of hazards and risks, and communication of safety information. His research has addressed consumer products in various hazard categories such as electrical, mechanical, and chemical, as well as products used in various work and home environments. He also studies the characteristics of people who influence the acquisition of such products and the use of such knowledge. Dr. Laughery applies a cognitive psychology perspective to address questions about the effectiveness of communication in terms of attention, comprehension, and resulting decision behavior. His studies have employed a variety of methodologies, ranging from laboratory experiments to field observations. Before 1984, Dr. Laughery was chairman of industrial engineering and head of the cognitive psychology area at the State University of New York at Buffalo. He has published more than 200 journal articles and technical reports in the areas of cognitive and applied psychology.

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, 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, he is investigating the factors governing appropriate reliance on automation.

CHRISTINE M. MITCHELL (see Board sketches, above)

D. ALFRED OWENS is a professor of psychology at Franklin and Marshall College. His expertise includes both basic and applied research in perception. A focus of his research has been the application of fundamental principles of perception to the assessment of human performance in applied settings. In addition to his professorship at Franklin and Marshall, Dr. Owens teaches the University of Michigan's national course on human factors, and he served previously on other NRC panels. Dr. Owens received his Ph.D. from the Pennsylvania State University.

Survivability and Lethality Analysis Panel

DAVID R. FERGUSON (see Board sketches, above)

DAVID BARTON (panel member in 2001) is executive vice president at ANRO Engineering. Previously, he served in a number of scientific research positions at Raytheon Company and at RCA and with the U.S. Army Signal Corps. He has authored numerous books and periodicals on radar systems analysis. Mr. Barton is a fellow of the IEEE and a former member of the Air Force Scientific Advisory Board and the NRC's Air Force Studies Board. Mr. Barton also served on the former ARL Technical Review Board and is a member of the NAE. He has a degree in physics from Harvard College.

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 (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 ASME, the American Society for Engineering Education, the Society of Engineering Science (SES), and the American Academy of Mechanics. He is the recipient of the 1992 Humboldt Award for Senior Scientists and the 2000 Eric Reissner Medal from the International Society of Computational Engineering and Sciences for contributions to the mechanics of penetration, and 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, senior fellow at the Logistics Management Institute, has an extensive background in DOD acquisition policy and program analysis. From 1989 to 1993, Dr. Christie was 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 to all defense acquisition policies and procedures resulting in the cancellation and consolidation of 500 prior separate issuances. He has served on numerous DOD advisory committees and a number of NRC committees.

STEPHEN D. CROCKER is 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 communication 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, 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 is the 2002 recipient of the IEEE Internet Award.

ARTHUR GUENTHER (see Board sketches, above)

DANIEL N. HELD is director and chief architect for netted strike in the Electronic Systems Sector of Northrop Grumman. Previously, he served as 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 NAE. 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 more than 180 technical publications, has edited 6 books, and is the coauthor of 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 for the American Institute of Aeronautics and Astronautics on these topics, both of which are taught at the Naval Postgraduate School. He has assembled a team at Raytheon, which 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 area manager with the Xerox Palo Alto Research Center. Before joining Xerox, she was 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, ACM, the International Federation for Information Working Group 11.3 on database security and Working Group 10.4 on reliability, and 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. She 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, the IEEE Computer Society, and ACM, and 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 senior research scientist and statistics group leader at 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 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 (ASB) 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 Laboratory's 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 TARA reviews.

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

JOHN C. SOMMERER 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 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 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.

EDWARD J. WEGMAN (panel member in 2001) is the Bernard J. Dunn Professor of Information Technology and Applied Statistics, chairman of the Department of Applied and Engineering Statistics, and director of the Center for Computational Statistics at George Mason University. His specialization is in computational statistics, nonparametric functional inference and splines, isotonic methods, statistical signal processing and time series analysis, and parallel processing. Previously, he was head of the Mathematical Sciences Division at the Office of Naval Research, was program director of the basic research program in ultrahigh-speed computing at the Strategic Defense Initiative’s Innovative Science and Technology Office, and was on the faculty of the Department of Statistics at the University of North Carolina. He has been a consultant to the states of North Carolina and Ohio, to the U.S. Navy, and to the Office of Management and Budget. Dr. Wegman is on the editorial boards of four professional journals, and he is a former editor of the *Journal of the American Statistical Association*. He is an elected member of the International Statistical Institute; a fellow of the American Statistical Association, AAAS, and the Institute of Mathematical Statistics; a senior member of IEEE; and the founder of the Interface Foundation of North America. Dr. Wegman received his Ph.D. in mathematical statistics from the University of Iowa.

Appendix C

Panel Meeting Agendas, 2001 and 2002

AIR AND GROUND VEHICLE TECHNOLOGY PANEL

April 17-19, 2002
Hampton, Virginia

Wednesday, April 17

CLOSED SESSION

7:30 a.m. Panel breakfast meeting at hotel

OPEN SESSION

9:00 a.m. Van ride to Vehicle Technology Directorate (VTD) offices at NASA Langley Research Center
10:00 a.m. Vehicle Technology Directorate overview
10:15 a.m. Loads and Dynamics Division overview
10:30 a.m. Active Twist Rotor Progress
11:00 a.m. MacroFiberComposite Actuators
11:30 a.m. "Skip-level" lunch with VTD staff
1:00 p.m. Crash Dynamics—overview
1:15 p.m. Experimental Techniques for Full-scale Crash Testing
1:45 p.m. Crash Simulation of the Sikorsky Advanced Composite Airframe Program Helicopter and Model Validation
2:15 p.m. Composite Fuselage Tests and Analyses
2:45 p.m. Break
3:00 p.m. Nonlinear Mechanics
4:00 p.m. VTD-Glenn overview
4:30 p.m. Active Stall Control Engine Technology Program
5:00 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Panel dinner meeting

Thursday, April 18

OPEN SESSION

7:45 a.m. Van ride to VTD offices at NASA Langley Research Center
8:15 a.m. Continental breakfast with VTD researchers and managers
9:00 a.m. Structural Mechanics Division overview
9:30 a.m. Skin/Stringer Debonding Analysis Methods
10:30 a.m. Tension-bending Fatigue of Composite Flexbeams
11:00 a.m. Low-velocity Impact Damage of Composites
11:30 a.m. Lunch
12:30 p.m. Probabilistic and Nondeterministic Methods
1:00 p.m. Coupled Meshless-finite Methods
1:30 p.m. Research on Advanced Aircraft Structural Concepts
2:00 p.m. Fatigue Life Methods for Metallic Rotorcraft Structures
2:30 p.m. Threshold Fatigue Crack Growth of Metallic Materials
3:00 p.m. Break

CLOSED SESSION
3:15 p.m. Panel in closed session

OPEN SESSION
3:45 p.m. Question and answer session—open to all VTD researchers and managers
4:45 p.m. Adjourn

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

Friday, April 19

OPEN SESSION
8:00 a.m. Wrap-up with senior VTD management at Radisson Hampton Hotel

CLOSED SESSION
9:30 a.m. Panel writing and convergence session
12:00 p.m. Adjourn

ARMOR AND ARMAMENTS PANEL

July 16-18, 2001
Aberdeen Proving Ground, Maryland

Monday, July 16

CLOSED SESSION

7:30 a.m.	Panel breakfast meeting at hotel

OPEN SESSION

9:00 a.m.	Travel to Aberdeen Proving Ground (APG), Rodman Materials Research Laboratory
9:30 a.m.	Introduction and opening observations
9:45 a.m.	Welcome and overview
10:30 a.m.	Break

I. Robotics

10:45 a.m.	ARL Robotics Program
11:25 a.m.	Designing a Behavior Development Environment for Unmanned Ground Vehicles
11:50 a.m.	Lunch

II. Gun-related Research

1:00 p.m.	Electronically Reliable Munitions
1:25 p.m.	Computational Chemistry Models of Gun Tube Erosion
1:50 p.m.	Barrel Reshaping Initiative—Research and Experiment

CLOSED SESSION

III. Lightweight Vehicle Protection

2:15 p.m.	Overview

IIIA. Kinetic Energy Active Protection

2:35 p.m.	Overview
3:00 p.m.	Break
3:15 p.m.	Muzzle Flash Experiments
3:40 p.m.	Kinetic Energy Tracking
4:05 p.m.	Blast Deflection—Modeling and Experiment
4:30 p.m.	Contact Fracture—Modeling and Experiment
4:55 p.m.	Questions and answers
5:30 p.m.	Adjourn for day

CLOSED SESSION

7:00 p.m.	Panel dinner meeting

Tuesday, July 17

OPEN SESSION

IIIB. Composites

8:00 a.m.	Overview for Composites
8:20 a.m.	Control of Fiber-matrix Interphase Properties in Composite Materials
8:45 a.m.	Silicate Nanocomposites
9:10 a.m.	Composite Structural Armor: Composite Modeling
9:35 a.m.	Composite Structural Armor: Model Integration and Design Optimization
10:00 a.m.	Break
10:15 a.m.	Metal Matrix Composites for Ordnance Applications
10:40 a.m.	Electron Beam Curing of Composites
11:05 a.m.	Magnetic Materials for Curie Temperature-Controlled Heating
11:30 a.m.	Low-cost Composites Processing
11:55 a.m.	Lunch with ARL Researchers

IV. Personnel Protection

1:00 p.m.	Personnel Protection Overview
1:20 p.m.	Improved Ceramic for Armor Applications
1:45 p.m.	Hybrid Hard/Ductile Composites for Transparent Lightweight Armors
2:10 p.m.	Personnel Protection: Material Modeling for Body Armor
2:25 p.m.	Blunt Force Trauma Modeling
2:50 p.m.	Break

V. Enabling Materials

3:05 p.m.	Enabling Materials Overview
3:20 p.m.	Ionomer and Hybrid Membranes
3:45 p.m.	ARL Nanobiotechnology Program
4:10 p.m.	Molecularly Imprinted Polymer for Chemical Agent Detection
4:35 p.m.	Electric Thin Film Materials Research

CLOSED SESSION

5:00 p.m.	Panel meeting

OPEN SESSION

5:15 p.m.	Questions and answers
5:45 p.m.	Adjourn for day

CLOSED SESSION

7:00 p.m.	Panel dinner meeting

Wednesday, July18

OPEN SESSION

8:00 a.m. Panel breakfast meeting with senior ARL/Weapons and Materials Research Directorate (WMRD) staff at hotel

CLOSED SESSION

9:30 a.m. Closed panel convergence and writing session

12:00 p.m. Adjourn

ARMOR AND ARMAMENTS PANEL

June 3-5, 2002
Aberdeen Proving Ground, Maryland

Monday, June 3

CLOSED SESSION

7:00 a.m. Panel breakfast at hotel

OPEN SESSION

8:45 a.m. Travel to APG, Rodman Materials Research Laboratory
9:25 a.m. Introduction and opening observations
9:30 a.m. Welcome and overview

I. Lethality—Energetics

10:00 a.m. Re-energizing Energetics at ARL
10:25 a.m. Smart Design of Insensitive High-Energy Materials Using Theoretical Chemistry
10:50 a.m. Applications of Atomistic Simulations to the Prediction of Propellant Properties
11:15 a.m. Towards Predicting Vulnerability of Propellants with Small-scale Experiments and Simulations
11:40 a.m. Lunch (Robotics Demo III Video shown)
12:15 p.m. Development and Application of NGEN for the Modular Artillery Charge Systems (MACS)
12:40 p.m. The Design and Screening of New Hypergolic Missile Propellants Through Computational Chemistry
1:05 p.m. Ammonium Dinitramide (ADN) Combustion: Chemical Mechanisms and Burn Rate Prediction
1:30 p.m. LIBS—Laser Induced Breakdown Spectroscopy for Chemical Detection
1:55 p.m. Questions and answers
2:15 p.m. Break and poster sessions

1. Polymer Modeling for Smart Munitions Electronics
2. Modeling Gas Surface Interactions in Gun Tube Erosion
3. Molecular Simulation of Shocked Materials Using Reactive Monte Carlo
4. Plasma Propellant Interactions
5. Flame Diagnostics Validation of Energetic Material Decomposition and Soot Formation Mechanisms
6. Energy Transport by Radiation in Electrothermal-Chemical-Ignited Propelling Charges
7. Composite Overwrap Technologies for Ceramic Gun Barrels
8. Photonic Bandgap Materials for Advanced Sensors and Devices
9. Optical Strain Monitoring Technique for Composite Flywheel
10. Lightweight Small-caliber Ammunition Using Advanced Polymeric Materials

II. Enabling Materials

3:15 p.m. Overview
3:35 p.m. Perm Selective Membranes

4:00 p.m.	Ferroelectric Materials
4:25 p.m.	Composites Manufacturing Army Science and Technology Objective (STO)
4:50 p.m.	Questions and answers
5:05 p.m.	Adjourn for day

CLOSED SESSION

7:00 p.m.	Panel dinner meeting

Tuesday, June 4

OPEN SESSION

7:00 a.m.	Travel to APG
7:30 a.m.	Continental breakfast with WRMD staff

CLOSED SESSION

III. Lethality—Warheads and Projectiles

8:00 a.m.	Overview
8:20 a.m.	Thermobarics
8:45 a.m.	Theoretical Background of Adiabatic Shear
9:00 a.m.	Implementation and Validation Models for Adiabatic Shear
9:25 a.m.	Break
9:40 a.m.	Penetrator Materials
10:20 a.m.	Penetrator Fracture
10:45 a.m.	Novel Lethal Mechanisms for KE Missiles
11:10 a.m.	Questions and answers
11:30 a.m.	Tour of Solid Mechanics Facility

OPEN SESSION

12:00 p.m.	Lunch with researchers

IV. Enabling Materials (cont'd), Electromagnetic (EM) Gun

1:00 p.m.	Ceramic Gun Barrel STO
1:25 p.m.	EM Gun
1:50 p.m.	Questions and answers

V. Lethality—Smart Munitions

2:05 p.m.	Multidisciplinary Design for Smart Munitions
2:15 p.m.	Multidisciplinary High-performance Computing for Smart Munition Design
2:55 p.m.	Experimental Sensor Systems for Smart Munitions
3:35 p.m.	Gun-launched Silent Operating Aerial Reconnaissance
3:50 p.m.	Comments on tour
4:00 p.m.	Questions and answers
4:15 p.m.	Break
4:30 p.m.	Tour of Telemetry Integration Facility
5:00 p.m.	Adjourn for day

CLOSED SESSION

7:00 p.m. Panel dinner meeting

Wednesday, June 5

CLOSED SESSION

8:00 a.m. Panel meeting at hotel

OPEN SESSION

9:00 a.m. Panel breakfast meeting with senior WRMD staff at hotel

CLOSED SESSION

10:30 a.m. Closed panel convergence and writing session

12:00 p.m. Adjourn

DIGITIZATION AND COMMUNICATIONS SCIENCE PANEL

July 30-August 1, 2001
Adelphi, Maryland

Monday, July 30

CLOSED SESSION

7:30 a.m.	Panel working breakfast, Holiday Inn, Silver Spring

OPEN SESSION

9:00 a.m.	Carpool to Army Research Laboratory
9:30 a.m.	Welcome to ARL
9:45 a.m.	Computational and Information Sciences Directorate (CISD) overview
10:30 a.m.	Communications and Networks Collaborative Technology Alliance (CTA)
	Advanced Decision Architecture CTA
	Robotics CTA
	Army Center of Excellence for Information Science
11:00 a.m.	Break
11:15 a.m.	Advanced Displays Federated Laboratory Close-out and Transition
11:45 a.m.	Center for Geo-Sciences: Atmospheric Research (CGAR)
	University Partnering for Operational Support (UPOS)
12:15 p.m.	Lunch
1:00 p.m.	Weather Effects Modeling Using U.S.Army High-performance Computing (HPC) Resources
1:30 p.m.	Signature Modeling
2:15 p.m.	Computational Characterization of Nerve Agent Activity and Inhibition
2:45 p.m.	Break
3:00 p.m.	Computational Multiscale Homogenization Method for Transient ElastoPlastic Heterogeneous Continua
3:30 p.m.	Composite Manufacturing Simulations Using Large-scale Parallel HPC Systems
4:00 p.m.	Poster session by Ph.D. students
5:00 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner

Tuesday, July 31

OPEN SESSION

7:15 a.m.	Carpool to Army Research Laboratory
8:00 a.m.	Informal continental breakfast with CISD staff
8:30 a.m.	Integrated Meteorological Support
9:30 a.m.	Acoustics Propagation Studies
10:15 a.m.	Break
10:30 a.m.	Collaborative Technology for the Warfighter—STO
11:15 a.m.	Advanced Battlefield Processing Technology—STO

12:00 p.m. Lunch (“skip-level” lunch with nonmanagement CISD technical staff)
1:00 p.m. Agentization of the Battlefield
1:45 p.m. Networked Sensors—Advanced Technology Demonstration
2:30 p.m. Break
2:45 p.m. Telecommunications Federated Laboratory Close-out and Transition

CLOSED SESSION
3:30 p.m. Closed panel session

OPEN SESSION
4:15 p.m. Panel question and answer session with CISD staff
5:00 p.m. Adjourn

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

Wednesday, August 1

OPEN SESSION
8:00 a.m. Panel working breakfast with senior CISD managers, Holiday Inn, Silver Spring
9:30 a.m. Break

CLOSED SESSION
9:45 a.m. Panel discussion and writing session
12:00 p.m. Adjourn

DIGITIZATION AND COMMUNICATIONS SCIENCE PANEL

June 5-7, 2002
Adelphi, Maryland

Wednesday, June 5

CLOSED SESSION

7:30 a.m.	Panel breakfast meeting at hotel

OPEN SESSION

9:15 a.m.	Panel en route to ARL
9:45 a.m.	Welcome to ARL
10:15 a.m.	CISD overview
11:00 a.m.	Break
11:15 a.m.	Communication and Networks Collaborative Technology Alliance
12:30 p.m.	Advanced Decision Architectures CTA—CISD Research
12:45 p.m.	Robotics CTA—CISD Research
1:00 p.m.	Lunch
1:45 p.m.	New Capabilities: Atmospheric Boundary Layer Exploitation (ABLE) and Computational Micrometeorological Modeling
2:15 p.m.	New Capabilities: Laser Optics/Communications
2:45 p.m.	New Capabilities: Quantum Computing
3:15 p.m.	Break
3:30 p.m.	Command and Control in Complex and Urban Terrain—STO (P)
4:15 p.m.	Fusion-based Knowledge for the Objective Force—STO (P)
4:30 p.m.	Computational Science and Engineering—New Initiatives
5:15 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner

Thursday, June 6

Parallel Session I (Battlefield Environment—Collaboratorium)

OPEN SESSION

8:00 a.m.	Continental breakfast with staff
8:30 a.m.	Battlefield Environment Division overview
9:15 a.m.	Signature Modeling and Chemical-Biological Applications
9:30 a.m.	Center for Geo-Sciences: Atmospheric Research
9:45 a.m.	University Partnering for Operational Support
10:00 a.m.	High-resolution Modeling of Acoustic Wave Propagation in Atmospheric Environments Common High-performance Scalable Software Initiative (CHSSI) Project
10:20 a.m.	Break
10:35 a.m.	High-resolution Multiscale Meteorological Modeling
11:25 a.m.	Urban/Canopy Transport and Dispersion Modeling
12:15 p.m.	Lunch with staff

1:15 p.m. Exploitation of Remote Sensing for Urban Combat
2:05 p.m. Mobile Weather Technology for the Objective Force
2:25 p.m. Environmental Effects on Infrasonic Arrays
2:50 p.m. Break
3:20 p.m. Exploitation of Polarimetric Imaging (Demo)

CLOSED SESSION
4:00 p.m. Panel private meeting

OPEN SESSION
4:30 p.m. Panel question and answer session with CISD staff
5:00 p.m. Adjourn

Parallel Session II (Information Assurance—Corporate Board Room)

OPEN SESSION
8:00 a.m. Continental breakfast with staff
8:30 a.m. Computer and Communication Sciences Division overview
9:15 a.m. Signal Processing for Mobile Communications
9:50 a.m. Free Space Laser Communications Using a Partially Coherent Beam
10:20 a.m. Break
10:35 a.m. Distributed Intrusion Detection Using Fuzzy Logic Data Mining
11:05 a.m. Energy-efficient Mobile Code Authentication
11:40 a.m. Vulnerability Agents (Federated Laboratory Close-out and Transition)
12:15 p.m. Lunch with staff
1:15 p.m. Multidisciplinary University Research Initiative (MURI)—Critical Information Protection
1:50 p.m. Intelligent Agents for C4ISR and Robotics
2:25 p.m. Heterogeneous Agent Systems
2:50 p.m. Break
3:10 p.m. Interlingua-based Machine Translation of Spatial Expressions
3:50 p.m. Simulation Research for Dismounted Soldier Training and Mission Rehearsal

CLOSED SESSION
4:00 p.m. Panel—private meeting

OPEN SESSION
4:30 p.m. Panel question and answer session with CISD staff
5:00 p.m. Adjourn

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

Friday, June 7

OPEN SESSION
9:00 a.m. Working breakfast and discussion with senior CISD managers
10:30 a.m. Break

CLOSED SESSION

10:45 a.m. Panel discussion and writing session—private meeting

12:00 p.m. Adjourn

SENSORS AND ELECTRON DEVICES PANEL

July 11-13, 2001
Adelphi, Maryland

Wednesday, July 11

CLOSED SESSION

7:30 a.m.	Panel working breakfast, Holiday Inn, Silver Spring

OPEN SESSION

9:00 a.m.	Carpool to Army Research Laboratory
9:45 a.m.	Welcome
10:00 a.m.	Sensors and Electron Devices Directorate (SEDD) overview
10:45 a.m.	Nanoscience
11:00 a.m.	Bioelectronics
11:15 a.m.	Signature Modeling
11:30 p.m.	Power and Energy
11:50 p.m.	Lunch
12:45 p.m.	Federated Laboratory Wrap-up and Display
1:10 p.m.	Radio-frequency Sensor and Device Technology
1:35 p.m.	Frequency Control
2:00 p.m.	Dynamic Re-Targeting
2:20 p.m.	Break
2:30 p.m.	Radar Sensors for Active Protection
2:50 p.m.	Foliage Penetration Technologies
3:30 p.m.	Directed Energy and Power
4:00 p.m.	Agile Target Effects
4:20 p.m.	Ground Vehicle Stopper
5:00 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner

Thursday, July 12

OPEN SESSION

7:15 a.m.	Carpool to Army Research Laboratory
8:00 a.m.	Informal breakfast with SEDD technical staff
8:45 a.m.	Technology Area Electro Optics
9:15 a.m.	High Energy Lasers
9:40 a.m.	Interband Cascade Laser
10:05 a.m.	Luminescent Material and Devices
10:30 a.m.	Break
10:55 a.m.	Optical Interconnect/Processing
11:20 a.m.	Tour Molecular Beam Epitaxy and Microelectromechanical Systems Fabrication Facilities
12:00 p.m.	Lunch (“skip-level” lunch with nonmanagement SEDD technical staff)

12:55 p.m. Spintronics
1:20 p.m. Quantum Computing
1:45 p.m. Quantum Structures
2:10 p.m. Photo Detectors for LADAR
2:35 p.m. Break
3:00 p.m. Autonomous Sensing
3:30 p.m. Magnetics
3:45 p.m. Electric Field Sensors
4:00 p.m. Break

CLOSED SESSION
4:10 p.m. Closed panel session

OPEN SESSION
4:40 p.m. Wrap-up
5:30 p.m. Adjourn

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

Friday, July 13

OPEN SESSION
8:00 a.m. Panel working breakfast with senior SEDD managers, Holiday Inn, Silver Spring

CLOSED SESSION
9:30 a.m. Panel working session
12:00 p.m. Adjourn

SENSORS AND ELECTRON DEVICES PANEL

May 1-3, 2002
Adelphi, Maryland

Wednesday, May 1

CLOSED SESSION

7:00 a.m.	Panel working breakfast, Holiday Inn, Silver Spring

OPEN SESSION

8:30 a.m.	Carpool to Army Research Laboratory
9:30 a.m.	Welcome
9:45 a.m.	Sensors and Electron Devices Directorate (SEDD) overview
10:25 a.m.	Cold Atoms
10:50 a.m.	Break
11:00 a.m.	Power and Energy
11:40 a.m.	Fuel Cells
12:05 p.m.	Lunch
12:35 p.m.	Electrolytes for High-energy Batteries
1:00 p.m.	Silicon Carbide/Wide Band Gap
1:25 p.m.	High-energy Batteries
1:50 p.m.	Advanced Sensors CTA
2:15 p.m.	Break
	Demo: Matrix Converter
2:25 p.m.	Electro-optic-Smart Sensors Thrust
2:50 p.m.	Electro-magnetic Modeling for Infrared (IR) Detectors
3:15 p.m.	IR Detector Research
3:40 p.m.	Ladar
4:05 p.m.	Break
	Demo: Passive IR Imaging
4:15 p.m.	Environmental Sensing
4:40 p.m.	Ultraviolet Opto-electronics for Environmental Sensing
5:05 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Panel working dinner

Thursday, May 2

OPEN SESSION

8:00 a.m.	Breakfast with SEDD scientific staff
8:30 a.m.	Autonomous Sensing
9:15 a.m.	Ultrawideband Technology for Assured Mobility
9:40 a.m.	Imaging Automatic Target Recognition
10:05 a.m.	Break
10:15 a.m.	Acoustic Sensing
10:40 a.m.	Acoustic Signal Processing

11:05 a.m. Signal Processing
11:30 a.m. Magnetic Sensors
11:55 a.m. "Skip-level" lunch with scientists and engineers
1:00 p.m. Radio-frequency (RF) Sensor and Device Technology
1:20 p.m. Multifunction RF
1:45 p.m. Advanced RF Components
2:10 p.m. Nano- and Micro-electromechanical Systems Using Smart Materials for Future Combat Systems
2:35 p.m. Break
Demo: Multifunction RF Components
2:45 p.m. Ion Implantation Activation in SiC Devices
3:10 p.m. Passive Millimeter Wave
3:35 p.m. Signature Modeling

CLOSED SESSION

4:00 p.m. Closed panel session

OPEN SESSION

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

CLOSED SESSION

7:00 p.m. Panel working dinner

Friday, May 3

OPEN SESSION

8:00 a.m. Wrap-up breakfast meeting with senior SEDD management

CLOSED SESSION

9:30 a.m. Panel writing and convergence session
12:00 p.m. Adjourn

SOLDIER SYSTEMS PANEL

May 22-24, 2001
Fort Benning, Georgia

Tuesday, May 22

CLOSED SESSION

8:00 a.m.	Panel in closed session

OPEN SESSION

9:30 a.m.	Human Research and Engineering Directorate (HRED) welcome and overview
10:00 a.m.	Group 1—Cognitive Engineering STO
	Group 2—Cognitive Engineering and Visualization
11:00 a.m.	Group 1—Cognitive Engineering and Visualization
	Group 2—Cognitive Engineering STO
12:20 p.m.	Lunch at Military Operations in Urban Terrain (MOUT) site
1:00 p.m.	Groups 1 and 2—MANPRINT Support to MOUT Advanced Concept Technology Demonstration (ACTD)
2:00 p.m.	Groups 1 and 2—MANPRINT Support to MOUT ACTD (Tour of MOUT experimentation site)
2:00 p.m.	Overview
2:30 p.m.	Control Room
2:45 p.m.	MOUT site walk-through
3:15 p.m.	Groups 1 and 2—Travel to Simulation Center
3:30 p.m.	Groups 1 and 2—Tour of Simulation Center
3:30 p.m.	Overview
3:45 p.m.	Observation of data collection
4:00 p.m.	Simulation Center walk-through
4:30 p.m.	Adjourn
6:30 p.m.	Dinner—Panel and HRED staff together

Wednesday, May 23

OPEN SESSION

8:00 a.m.	Group 1—Cognitive Foundation of Performance in Military Environments
	Group 2—Soldier-centered Design Metrics
8:55 a.m.	Group 1—Soldier-centered Design Metrics
	Group 2—Cognitive Foundation of Performance in Military Environments
9:45 a.m.	Break
10:00 a.m.	Group 1—Crew Station Design
	Group 2—MANPRINT Support to Maneuver and Mobility Systems—Interim Armored Vehicle (IAV) Support
10:55 a.m.	Group 1—MANPRINT Support to Maneuver and Mobility Systems—IAV Support
	Group 2—Crew Station Design
11:45 a.m.	Lunch catered at MOUT site
12:15 p.m.	Group 1—MANPRINT Support to Maneuver and Mobility Systems—Mine Detection
	Group 2—CTA and Skill Enhancement

1:10 p.m. Group 1—CTA and Skill Enhancement
Group 2—MANPRINT Support to Maneuver and Mobility Systems—Mine Detection

CLOSED SESSION

2:00 p.m. Panel in closed session
5:00 p.m. Adjourn

Thursday, May 24

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 29-May 1, 2002
Aberdeen Proving Ground, Maryland

Monday, April 29

CLOSED SESSION

8:00 a.m.	Panel in closed session

OPEN SESSION

9:30 a.m.	En route to ARL/HRED
10:00 a.m.	Welcome and overview
10:40 a.m.	Group 1: Soldier-centered Design Tools for Army Transformation
	Group 2: Cognitive Foundation of Performance in Military Environments
11:35 a.m.	Group 1: Cognitive Foundation of Performance in Military Environments
	Group 2: Soldier-centered Design Tools for Army Transformation
12:30 a.m.	Lunch
12:50 p.m.	Dismounted Warrior Research overview
12:55 p.m.	Virtual Environments for Dismounted Soldier Simulation
1:15 p.m.	Range Safety Video
1:25 p.m.	Group 1 en route to M Range; Group 2 en route to KD Range
1:45 p.m.	Group 1: Shooter Performance Facility overview (M Range)
	Effect of Cognitive Load on Shooting Performance
	Small Arms Weapon Firing
	Group 2: Mobility-Portability Obstacle Course (KD Range) overview and studies
	Effect of Weapon Weight on Shooting Performance and Mobility
	Effects of Information Availability and Management on Dismounted Teams
2:40 p.m.	Group 1 en route to KD Range; Group 2 en route to M Range
2:45 p.m.	Group 1: Mobility-Portability Obstacle Course (KD Range) overview and studies
	Effect of Weapon Weight on Shooting Performance and Mobility
	Effect of Information Availability and Management on Dismounted Teams
	Group 2: Shooter Performance Facility overview (M Range)
	Effect of Cognitive Load on Shooting Performance
	Small Arms Weapons Firing
4:00 p.m.	Break
4:10 p.m.	En route to Tactical Environment Simulation Facility (TESF)
4:15 p.m.	Group 1 and 2: Introduction to TESF
4:20 p.m.	Group 1 and 2: Auditory Awareness and Speech Communications
6:30 p.m.	Dinner: Panel and HRED staff

Tuesday, April 30

OPEN SESSION

7:30 a.m.	En route to ARL/HRED
8:00 a.m.	Group 1: Advanced Decision Architectures CTA
	Group 2: Human Factors Engineering (HFE) and MANPRINT Support to Information Systems—Battlefield Combat Identification System (BCIS)

8:55 a.m.	Group 1:	HFE and MANPRINT Support to Information Systems—BCIS
	Group 2:	Advanced Decision Architectures CTA
10:00 a.m.	Group 1:	Visual Perception and Sensory Modeling
	Group 2:	Human Factors Analysis for Combat Service Support (CSS) Transformation
10:50 a.m.	Group 1:	Human Factors Analysis for CSS Transformation
	Group 2:	Visual Perception and Sensory Modeling

Depart for Ground Vehicle Experimentation Course

11:45 a.m.	Lunch
12:10 p.m.	Human Use
12:20 p.m.	En route to Bldg. 463 and Ground Vehicle Experimentation Course
12:25 p.m.	Group 1: Crewstation Integration and Automation Testbed
	Group 2: Soldier Performance and the Objective Force
	Group 2: Human Challenge with Vehicle Motion
	Group 2: Container Roll In–Roll Out Platform (CROP) and CROP Handler and Transporter (CHAT) Field Demonstration
1:15 p.m.	Group 1: Soldier Performance and the Objective Force
	Group 1: Human Challenge with Vehicle Motion
	Group 1: CROP and CHAT Field Demonstration
	Group 2: Crewstation Integration and Automation Testbed

CLOSED SESSION

2:10 p.m.	Panel in closed session
5:00 p.m.	Adjourn
7:00 p.m.	Dinner

Wednesday, May 1

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

June 6-8, 2001
Fort Monmouth, New Jersey

Wednesday, June 6

CLOSED SESSION

7:30 a.m.	Closed panel breakfast meeting at Holiday Inn, Tinton
9:00 a.m.	Travel and convene at Myer Center, Fort Monmouth
9:30 a.m.	Welcome and overview of SLAD/IEPD (Survivability and Lethality Analysis Directorate/Information and Electronic Protection Division)
10:30 a.m.	Overview of CECOM (Communication-Electronics Command)
11:00 a.m.	Overview of C4I (Command, Control, Communications, Computers, and Intelligence)
11:30 a.m.	Break
11:45 a.m.	Description of CEWIS (Communications Electronic Warfare Instrumentation System) Capabilities
12:00 p.m.	Demo of CEWIS-based Analysis of SINGGARS (Single-Channel Ground and Airborne Radio Systems) Radio
12:45 p.m.	Lunch
1:45 p.m.	Overview of U.S. Army GPS (Global Positioning System) User Equipment Battlespace Tactical Navigation
2:15 p.m.	Support to CECOM GPS Electronic Protection Program
2:45 p.m.	Demo of Joint SLAD/CECOM GPS Receiver Analysis
3:15 p.m.	Break
3:30 p.m.	Description of COTS (commercial off-the-shelf) Products Analysis
4:00 p.m.	Tour of Survivable Architecture Lab
4:15 p.m.	Analysis of Solaris/DII COE (Defense Information Infrastructure Common Operating Environment) to Support Army Battle Command System Fielding
5:00 p.m.	Recap/Questions and Answers
5:30 p.m.	Adjourn

CLOSED SESSION

7:00 p.m.	Closed panel dinner meeting

Thursday, June 7

CLOSED SESSION

7:45 a.m.	Travel and convene at Myer Center, Fort Monmouth
8:15 a.m.	Breakfast with SLAD personnel at Myer Center, Fort Monmouth
9:00 a.m.	SLAD Propagation Models Description
9:30 a.m.	SLAD Support to CECOM Tactical Internet
10:00 a.m.	CECOM Tactical Internet Models
10:30 a.m.	Break
10:45 a.m.	Description of CECOM C2P ATD (Command and Control Protection Advanced Technology Demonstration)
11:15 a.m.	Information Flow Model Description
11:45 a.m.	Demo of IFM (Information Flow Model) Support to Control Damage Testing

12:15 p.m. Lunch
1:15 p.m. CECOM I2WD (Intelligence and Information Warfare Directorate) Offensive IO (Information Operations) Program
1:45 p.m. FBCB2 (Force Battle Command Brigade and Below) Field Test Data Reduction Methodology
2:45 p.m. Break
3:00 p.m. Cellular Automata Model Development to Support FBCB2 Situation Awareness Analysis
3:30 p.m. Cellular Automata Model Development to Support FCS (Future Combat System) Info Sphere Analysis
4:00 p.m. Recap
4:15 p.m. Closed panel session
4:45 p.m. Questions and answers
5:30 p.m. Adjourn

CLOSED SESSION
7:00 p.m. Closed panel dinner meeting

Friday, June 8

CLOSED SESSION
8:00 a.m. Breakfast buffet and meeting with SLAD senior managers at Holiday Inn, Tinton

CLOSED SESSION
9:30 a.m. Closed panel convergence and writing session
12:00 p.m. Adjourn

SURVIVABILITY AND LETHALITY ANALYSIS PANEL

April 2-4, 2002
Aberdeen Proving Ground, Maryland

Tuesday, April 2

CLOSED SESSION

7:30 a.m. Closed panel breakfast meeting at Four Points Sheraton Hotel

OPEN SESSION

8:45 a.m. Van departure from hotel to APG
9:45 a.m. Panel introductions and opening observations
10:00 a.m. SLAD and Army Transformation overview
11:00 a.m. Ground Systems Introduction
11:20 a.m. Legacy Systems-Abrams
11:40 a.m. Legacy Systems-Crusader
12:00 p.m. Lunch
1:00 p.m. Legacy System-BAT and the Path Ahead for P3I BAT
1:20 p.m. Stryker (Interim Armored Vehicle (IAV))
2:00 p.m. Future Combat Systems
2:30 p.m. Break
3:00 p.m. Range Tours
4:45 p.m. Return to Four Points Sheraton Hotel
5:00 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Closed panel dinner meeting

Wednesday, April 3

OPEN SESSION

7:45 a.m. Van departure from hotel to APG
8:30 a.m. Call to order
8:30 a.m. Ballistic Research Laboratory Computer-aided Design (BRL-CAD) Update
9:15 a.m. Modular UNIX-based Vulnerability Estimation Suite (MUVES) Update/Follow-On
10:15 a.m. Break
10:30 a.m. Target Interaction Lethality Vulnerability (TILV)/Technology Area Review and Assessment (TARA)
11:15 a.m. Attrition Modeling: Vulnerability/Lethality
12:00 p.m. Working lunch with bench-level scientists and engineers
1:00 p.m. Virtual Live Fire Test and Evaluation
2:00 p.m. Objective Force nuclear, biological, and chemical warfare issues
2:45 p.m. Break

CLOSED SESSION

3:00 p.m. Panel deliberations—closed session

OPEN SESSION

4:00 p.m. Question and answer session with all SLAD participants
5:00 p.m. Adjourn

CLOSED SESSION

7:00 p.m. Closed panel dinner meeting

Thursday, April 4

OPEN SESSION

8:00 a.m. Breakfast buffet and meeting with SLAD senior managers at Four Points Sheraton Hotel

CLOSED SESSION

9:30 a.m. Closed panel writing and convergence session
12:00 p.m. Adjourn

Appendix D

Panel Assessment Criteria

FORMULATION OF THE PROJECT'S GOALS

- Is there a clear understanding of the Army's need for the R&D or analysis?

- Are appropriate scientific and technical objectives being posed, taking into consideration the Army's needs, ARL's strengths, and the time horizon for the project?

CONNECTIONS TO THE BROADER COMMUNITY

- Does the project plan reflect a broad understanding of the underlying science and of comparable work being done within other ARL units and within the Department of Defense, as well as in industry, academia, and other federal laboratories?

- Does the project build appropriately on work already done elsewhere? Have the investigators leveraged the work of leaders in the field? Are partnerships, if any, well chosen and managed?

METHODOLOGY

- How well crafted are the project plans? Is the use of laboratory experiment, modeling, simulation, and/or field test appropriate? How well are these integrated?

- Are the choice and use of equipment appropriate? The data collection and analysis?

- Are the conclusions supported by the results? Are the ideas for further study reasonable?

OVERALL CAPABILITIES

- Is the scientific or engineering quality of the work comparable to similar efforts at competing institutions, and is it appropriate for the goal?

- What are the qualifications of the scientific and engineering staff?
- How is the morale of the scientific and engineering staff?
- What is the state of the equipment and facilities?

PRODUCTS

- Does the work being examined appear to be considered significant by the cognizant field of science or technology? Does it result in peer-reviewed publications? What technical products (e.g., patents, patent licensing agreements, software, as appropriate) have resulted?

Appendix E

Selected Acronyms

ACT	Adaptive Character of Thought
ACTD	advanced concept technology demonstration
APG	Aberdeen Proving Ground
ARI	Army Research Institute
ARL	Army Research Laboratory
ARO	Army Research Office
ATD	advanced technology demonstration
BRL-CAD	Ballistic Research Laboratory Computer-aided Design (software)
BST	barium-strontium titanate
C&C	computer and communication
CECOM	Communication-Electronics Command
CGAR	Center for Geo-Sciences: Atmospheric Research
CISD	Computational and Information Sciences Directorate
COTS	commercial off-the-shelf
CTA	Collaborative Technology Alliance
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DOE	Department of Energy
EM	electromagnetic
EMVAF	Electromagnetic Vulnerability Assessment Facility
FAA	Federal Aviation Administration
FCS	Future Combat System
FY	fiscal year

HPC	high-performance computing
HRED	Human Research and Engineering Directorate
HSIAC	Human Systems Information Analysis Center
IEPD	Information and Electronic Protection Division (SLAD)
IMETS	Integrated Meteorology System
IO	information operations
IP	Internet Protocol
IPA	Intergovernmental Personnel Act
IR	infrared
MEMS	microelectromechanical systems
MMIC	monolithic microwave integrated circuit
MMW	millimeter wave
MOUT	military operations in urban terrain
MSRC	Major Shared Resource Center
MSU	Mississippi State University
MURI	Multidisciplinary University Research Initiative
NAE	National Academy of Engineering
NASA	National Aeronautics and Space Administration
NRC	National Research Council
RAB	research advisory board
R&D	research and development
RDEC	Research, Development, and Engineering Center
S&Es	scientists and engineers
SEDD	Sensors and Electron Devices Directorate
SLAD	Survivability and Lethality Analysis Directorate
SPIE	Society for Photo-Optical Instrumentation Engineers
STO	Science and Technology Objective
TAB	Technical Assessment Board
TARA	Technology Area Review and Assessment
UPOS	University Partnering for Operational Support
VARTM	vacuum-assisted resin transfer molding
VTD	Vehicle Technology Directorate
WMRD	Weapons and Materials Research Directorate