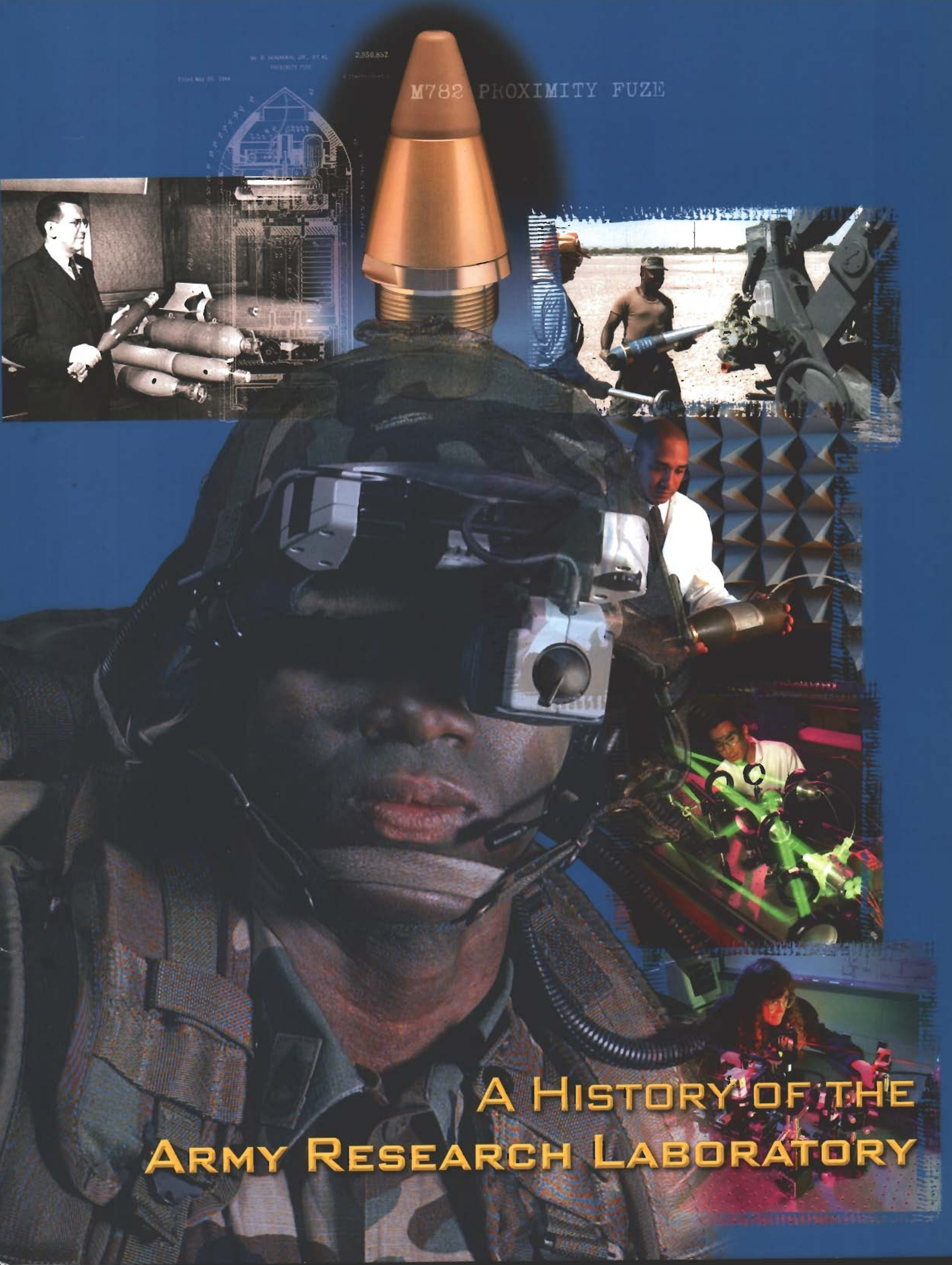

A History of the Army Research Laboratory

August 2003

A Message from the Director

John Miller
Acting Director, ARL

ARL's history has been a story of success. Since the laboratory's inception in 1992, our mission has been to provide innovative science, technology, and analyses to enable execution of full-spectrum operations. While the mandate has been consistent, ARL has had to adapt to implement it. Fortunately, our efforts have paid significant dividends, as ARL technology has been deployed in major Army systems and we continue to conduct research critical to the success of Army Transformation and ongoing operations in the Middle East and Afghanistan.

ARL has maintained its level of quality research and analysis despite undergoing various transitions that are inevitable with the establishment of a new organization. Credit for the steadiness of our efforts goes to our scientists and engineers, who continue to focus on the issues that are essential to the Future Force. American success on the battlefield depends in part on the technology developed by both our basic and applied research. ARL's excellence as a developer of Army technology hinges on its dedication to both research and analysis, and a priority on employing and maintaining top-notch scientists and engineers.

In addition to scientific and engineering endeavors, ARL recognizes that the development of new technology requires innovative thinking concerning organizational matters. In the past ten years, we have seen ARL develop as an organization through the consolidation of directorates, new hiring initiatives that have expanded ARL's diversity and talent pool, and enhanced partnerships that allow us to leverage and incorporate research being done in both academia and the private sector. Finally, all of these initiatives are made possible by ARL's state-of-the-art facilities, many of which have been constructed in the past ten years.

But despite all of the advances of the past ten years, we will not rest on our laurels. The 21st century presents new challenges for the Army, and ARL stands ready to meet those challenges. This history of ARL establishes where we have been, but perhaps more importantly, reminds us of where we must go. As we look back on our first ten years, we are proud of all we have accomplished. But we are committed to meeting the challenges of the future that will ensure the Army's continued technological superiority.

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ARL has continued the Army tradition of technological innovation exemplified by development of the ENIAC computer.

Prelude: Before ARL

1945-1990 1991 1993-1998 1998-2001 2001 & beyond

Today's military laboratory system has deep roots, going back to the early years of the nineteenth century when America first found its footing on the international stage. Military research began in the United States with ordnance supply and Army medical research. By 1820, the Army had its first laboratory at Watertown Arsenal in Massachusetts. Rudimentary by today's standards, the early laboratory researched pyrotechnics and waterproof paper cartridges.

More than 100 years later in 1945, the Army published its first official policy on research and development (R&D), formally recognizing the need for civilian scientific assistance in military planning and weapons production. The Research and Development Division of the War Department General Staff was established on June 11, 1946, marking the first time R&D was recognized as a separate military effort. The initiative, however, didn't last.

In 1947, the R&D Division was abolished as a separate unit and redesignated a group in the Service, Supply, and Procurement Division of the General Staff. Civilian scientists, though, campaigned for recognition. Opposition to establishment of a separate R&D command or element came from Army staff and technical service chiefs who opposed dismantling the traditional technical service structure.

The scientists eventually got their wish. The Office of the Chief of Research and Development emerged as an independent General Staff agency in 1955. At about the same time, the civilian position of director of R&D was established at the Army assistant secretary level. This action reflected the influence of the Army Scientific Advisory Panel, a group of civilian scientists and industrialists.

General reorganization of the Army in 1962 heavily impacted R&D alignment, and the Army Materiel Command (AMC) inherited the procurement and development functions for weapons and munitions. From the beginning, AMC encountered problems in balancing its two basic missions: systems acquisition and readiness. In 1966, the Commanding General, AMC appointed a Deputy for Research and Laboratories to exercise direct line authority over the nine AMC central laboratories and over the technical quality of research conducted in the laboratories of AMC's Major Subordinate Commands (MSCs). In 1969, AMC established two deputy

The establishment of the U.S. Army Laboratory Command...

represented the Army's recognition of the

ARL Laboratories:

Ballistic Research Laboratory

The Ballistic Research Laboratory (BRL) was activated during World War I to meet increased demands for firing tables and other ballistic data. By that time, practically all of the test and experimental work was conducted at Aberdeen Proving Ground, MD, which had been established in 1917 to replace inadequate facilities and space at the Sandy Hook Proving Ground, NJ.

Thanks to careful planning, BRL expanded in a rapid but orderly manner to meet wartime demands. In 1943, the Ordnance Department designated BRL its principal research organization.

In the postwar period, BRL pioneered development of high-speed computers and electronic devices, which greatly enhanced its ability to analyze weapons systems. This expanded scope was reflected in new construction, such as the wing that housed ENIAC (electronic numerical integrator and computer)—the Army's first computer. BRL served as home to the Army's first two supercomputers. Significantly, appropriations after World War II continued at levels even higher than those reached in wartime budgets.

During the Army reorganization in 1962, BRL was transferred into AMC and reported directly to Headquarters as a corporate laboratory. Over the next 20 years, BRL was attached to the Aberdeen Research & Development Center (ARDC), and then later to the Armaments R&D Center. But in 1984, BRL was reassigned directly to AMC headquarters, again as a corporate laboratory. One year later, it became part of LABCOM.

BRL formed the core of ARL's Weapons and Materials Research Directorate, with computer technology elements migrating to the Computational and Information Sciences Directorate and vulnerability analysis efforts moving into the Survivability/Lethality Analysis Directorate.

commanding generals, one for materiel acquisition and one for logistics support.

AMARC (1973) to ERADCOM (1978-1985)

In 1973, the Secretary of the Army established the Army Materiel Acquisition Review Committee (AMARC), an ad hoc group consisting primarily of civilians from outside the government with a charter to analyze the entire materiel acquisition process and to recommend improvements. The committee noted the progress achieved over the previous ten years, but found a number of weaknesses in the scientific development and technology areas.

To address some of these deficiencies, AMARC proposed to separate the management of new weapons systems and major product improvements from logistics management. In implementing this organizational concept, AMC discontinued its commodity commands and established parallel R&D and readiness commands.

AMC decided against establishing a Combat Support Center, moving instead to study the formation of a Harry Diamond Development Center (HDDC), based on an enhanced Harry Diamond Lab (HDL). DA evaluation favored establishing HDDC under AMC.

In 1977, the Deputy Secretary of Defense and the Secretary of the Army announced a modified plan for the organization of the Electronics Research and Development Command (ERADCOM) with headquarters to be collocated with HDL at Adelphi, MD, and on January 3, 1978, ERADCOM was formally activated. Thus, for the first time, the Army had a single command responsible for its combat electronics materiel.

ERADCOM to LABCOM

The conversion of ERADCOM to the U.S. Army Laboratory Command (LABCOM) represented the Army's recognition of the importance of research and development and its continual attempt to properly balance materiel development with logistics.

LABCOM was also the final realignment to result from reconsideration of AMARC recommendations.

The following were incorporated into LABCOM: Ballistic Research Laboratory (BRL) and Human Engineering Laboratory (HEL), both at Aberdeen Proving Ground, MD; Harry Diamond Laboratories (HDL), Adelphi, MD; Materials Technology Laboratory (MTL), Watertown, MA; Electronics Technology and Devices Laboratory (ETDL), Fort Monmouth, NJ; Vulnerability Assessment Laboratory (VAL) and Atmospheric Sciences Laboratory (ASL), both at White Sands Missile Range, NM; and Army Research Office (ARO), Research Triangle Park, NC.

LABCOM was activated in 1985 as the newest AMC MSC, and its business was research, with a mission to put scientific findings to maximum use on the battlefield. While threat capabilities were constantly changing and increasing, and revolutionary scientific discoveries promised exciting new capabilities, these circumstances also meant that even the most advanced equipment might be obsolete as soon as it was fielded. The key was to harness advanced technology to the Army's advantage; however, translating the abstractions of the laboratory to the real world of weapons and equipment was a critical challenge. It required multiplying the impact and product of Army technology resources by pooling efforts and capabilities, piggybacking programs on the advances of others, and executing breakthroughs as quickly as possible.

LABCOM managed the AMC corporate laboratories as well as specific technology-related programs that cut across the MSCs and mission-area lines. In addition, the corporate laboratories provided independent technical advice and R&D assessments to the Army.

Managing AMC'S Technology Base:

The establishment of LABCOM brought together under one MSC the AMC research laboratories that generated technolo-

ARL Laboratories:

Harry Diamond Laboratories

The history of the Harry Diamond Laboratories (HDL) dates back to 1940. Prompted by increasing warfare abroad, the National Defense Research Committee organized a group of scientists and engineers into the Ordnance Development Division of the National Bureau of Standards (NBS) to develop fuzes for non-rotating (e.g., fin-stabilized) munitions such as bombs, rockets and mortar shells. Harry Diamond, a pioneer radio engineer, was given technical direction of the program, a position he held until his death in 1948.

Proximity fuzes were first used in combat in January 1943, and the War Department later described the proximity fuze as "one of the outstanding scientific developments of World War II ...second only to the atomic bomb" in military importance.

In 1953, the Ordnance Development Division was transferred from NBS to the Army as an R&D installation and named the Diamond Ordnance Fuze Laboratories (DOFL) in honor of the early leader. DOFL made significant contributions in areas such as printed circuits, casting resins, flow and temperature measurement, reserve power supplies, high-resolution radar, air navigation systems and nuclear effects studies.

During the 1962 Army reorganization, DOFL was assigned directly to AMC as a corporate laboratory, and the next year, its name was officially changed to Harry Diamond Laboratories to reflect broadened, Army-wide missions. AMC later studied the possibility of establishing a Harry Diamond Development Center that would consolidate and integrate work in radar, lasers, electro-optics, signal intelligence and electronic warfare. Instead, AMC established ERADCOM as the overall command with HDL as a major element. HDL later became a critical component of LABCOM. At the time, HDL occupied a modern research facility located on 137 acres in Adelphi, MD. It also controlled two other sites: a test range at Blossom Point, MD, and research facilities at Woodbridge, VA.

gies and advanced concepts to carry the Army into the future. The corporate laboratories' programs were reoriented to concentrate on critical technology barriers related to the development and production of new Army systems, especially high-risk/high-payoff concepts that could significantly increase battlefield effectiveness. The strategic long-range plan called for identifying areas of common interest and focusing efforts on multi-laboratory, cooperative ventures. Four specific initiatives included smart weapons, enhancements to autonomous machines, active protection and vulnerability expert systems.

The technology integration effort, designed to leverage technologies being worked on elsewhere, allowed the Army to capitalize on advances made by others and, perhaps more importantly, to focus its resources on Army-critical issues while satisfying many of its needs from more generic R&D conducted in other sectors. Through the integration efforts, LABCOM forged close ties with private industry, other government agencies, academia and technology programs of foreign allies.

Technology developed by LABCOM's laboratories soon paid off in battle. In 1990, America went to war against Iraq, marking the Nation's first major combat involvement since the end of the Vietnam War. U.S. ground forces deployed to Saudi Arabia were equipped with systems that AMC R&D activities developed. For the first time in modern warfare, technological battlefield capabilities took center stage, leading American soldiers into battle and paving the way to a sweeping victory in the deserts of the Middle East.

Opposite: FALCon technology has marked a significant breakthrough in battlefield translation operations.

Applied research is fundamental to ARL's mission. As seen in the Titanium display below, ARL scientists often work with materials at the smallest levels.

Section I: Founding of ARL

1945-1990 **1991** 1993-1998 1998-2001 2001 & beyond

At approximately 4p.m. on February 26, 1991, at the line referred to as "73 Easting" by the U.S. military, a group of coalition tanks advanced on well-fortified Iraqi positions in southeast Iraq. The Desert Storm ground war had begun only two days earlier, on February 24, and coalition forces were hoping to push the Iraqis back and retake northern Kuwait. While resistance to the first 48 hours of U.S. ground attacks had been light, the looming battle at 73 Easting promised to be much different. Iraqi forces were attempting to stop an advance on Basrah, a port city just north of Kuwait and 50 miles inland from the Persian Gulf. Capturing the city would have effectively cut off most of the Iraqi forces from Kuwait. The Iraqis knew this and defended heavily all routes to the port, utilizing a large force of tanks and trucks. In addition to superior numbers, the Iraqi forces had a multitude of other factors on their side: they were defending familiar territory; their positions were well-entrenched and in some cases well-hidden by a sandstorm, and they were fighting coalition forces with little combat experience and no air cover. In contrast, many of the Iraqi commanders had been battle hardened by the recently concluded Iran-Iraq war. Essentially, the Iraqi forces had significant advantages in numbers, experience, and terrain factors.

Yet only 23 minutes into the battle, the Iraqi tank fleet had been utterly decimated. Twenty-eight Iraqi tanks, 16 personnel carriers, and 39 trucks were either completely destroyed or immobilized. As the once-proud Iraqi forces lay in smoking ruins on the windswept desert plain, coalition forces rounded up over 1300 prisoners. Even more surprising, not a single U.S. serviceman was killed in the battle. The lopsided victory was best described by an Iraqi commander, who noted that "On 17 January, I started with 39 tanks. After 38 days of aerial attacks, I had 32, but in less than 20 minutes with the M1A1, I had zero."*

How had the coalition forces overcome numerous disadvantages to turn the battle of 73 Easting into a complete rout? Certainly, the command decisions of Army leadership, along with the training and courage of American troops, were significant factors in the battle. But just as important was the technological superiority of the M-1, or "Abrams" tank that American soldiers brought into battle with them. LABCOM's laboratories had been significantly involved in fitting the tank, which featured M1A1

* Iraqi Battalion Commander, captured 16 April 1991. Relayed by Col. Don Holder, Commander, 2nd ACR.

Throughout history, advances in technology have supported U.S. soldiers in battle.

armor resistant to some Iraqi shells, the M829A2 armor-penetrating round, and significantly better weapons range. Quite simply, the U.S. tanks could see their enemy better, fire first in virtually every engagement, reload before many of the Iraqi gunners could get them in range, and withstand enemy fire at an unusual level. The U.S. could overwhelmingly outrun them and outgun them.

There could be no doubt that the United States' technological superiority had contributed significantly to overcoming the disadvantageous factors in the battle. While it was certainly not the first time in modern warfare that the more technologically advanced force defeated its opponent, it was significant given the strength of both the Iraqi position and numbers. Throughout history, advances in technology had supported U.S. soldiers in battle. Now, it could be argued that technology had vaulted itself onto center stage. With the Cold War at an end, the United States proved in the Persian Gulf War that it was significantly more advanced than the rest of the world in development and deployment of military technology. The decimation of the Iraqi tank forces at 73 Easting had decisively demonstrated that.

While the war was being waged and the technological superiority of the United States was being shown on the television screens of the entire world, steps had already been taken to ensure that future research efforts would preserve the U.S. military's position at the forefront of military technological development. The ability of the United States to repel Saddam Hussein's forces and restore peace to Kuwait with minimal casualties would not have been possible without the significant efforts of Army scientists and engineers over the previous decade. It was in this atmosphere, in which the importance of technology was growing almost daily, that the Army Research Laboratory was formed. Its mission was to conduct basic and exploratory research and analysis to ensure supremacy in future land warfare, in turn protecting both America and its soldiers.

The impetus for ARL grew out of efforts to realign the Army's technology base following the collapse of communism in Eastern Europe and the end of the Cold War. In December 1988, the Defense Secretary's Commission on Base Realignment and Closure (BRAC) identified the Army Material Technology Laboratory (MTL) at Watertown, MA for closure, primarily on grounds that MTL facilities needed major renovation or replacement. Missions and functions would be dispersed and the property sold, with transfers of functions scheduled for 1994 and all realignments completed by September 30, 1995. However, there were still questions as to where LABCOM fit into these realignment efforts.

LABCOM had been established as AMC's Major Subordinate Command (MSC), responsible for research laboratories that produced generic technologies and advanced concepts to carry the Army into the future. It was also recognized as the Corporate Technology Center that provided technical support and services to other MSCs and program executive officers. The LABCOM commander served as AMC's Deputy Chief of Staff for Technology Planning and Management (DCSTPM), coordinating approximately 75 percent of the Army's technology base effort. Combat systems supported by LABCOM included the Abrams (M1A1) main battle tank, the Bradley fighting vehicle, the PATRIOT point-defense antimissile system, the Multiple Launch Rocket System (MLRS), the High-Mobility, Multipurpose Wheeled Vehicle (HMMWV), which had been deployed in Panama, and the Army Tactical Missile System (ATACMS).

On January 6, 1989, the LABCOM Commander signed a memorandum stating the command's dedication to "accomplish materials research, development, and consultation requirements." In the ensuing months, LABCOM developed a proposal to move the core of materials research to one location as part of a concept for integrating the corporate laboratories into a single physical entity, which would eventally become the Army Research Laboratory (ARL).

In the same month that President Bush was inaugurated, the Defense Management Review (DMR) was launched, resulting in formation of the Army Management Review Task Force as a

ARL Fellows

In its first year, ARL reestablished the concept of a Fellows Program that consisted of senior scientists who served as honorary advisors to the Director. Implemented for LABCOM in 1989, the LABCOM Fellowship was a semi-independent and peer-elected consultative aid to the Commander. With the establishment of ARL, Mr. Richard Vitali, Acting Director, requested the continuance of the concept and accordingly the charter of the LABCOM Fellows was adapted to the new organization. The fellowship represented the highest accomplishments in science, mathematics, engineering, and analysis. A revised charter in 1996 stressed that the purpose of the ARL Fellows was to encourage the promotion of technical careers and scientific achievement within ARL by serving as an advocate for the ARL staff, promoting collaborative research and technical interchange with other scientists, encouraging participation in meetings, symposia, and publications outside DoD, and advocating stability of the basic and applied research, technology development, analysis, and technology base programs. The charter further emphasized that fellows serve as advisors and consultants on technical matters for the ARL Director and the Executives of the ARL Directorates. The Fellows program provides a forum for interaction among its members to exchange ideas, plan activities and perpetuate the organization, and promotes ARL values of excellence, commitment, integrity, and the best value of the Army.

ARL Laboratories:

Materials Technology Laboratory

The Materials Technology Laboratory (MTL) traces its roots back to 1800 with the establishment of an arsenal at Charlestown, MA on Boston harbor. Following the War of 1812, the Ordnance Department purchased land at Watertown, constructed buildings and transferred activities to Watertown, MA from Charlestown.

At its peak, the Watertown Arsenal encompassed an area of approximately 130 acres and employed 10,000 people. Originally established as a depot for the storage, cleaning, repair and issue of small arms and ordnance supplies, its activities were expanded to include the manufacture of field, siege and seacoast guns and carriages. In 1881, it assumed functions as a test and experiment unit.

Following extensive activity during World War I, the Arsenal made several important technical contributions, including developments in radiography, qualitative spectrum analysis and molybdenum high-speed tool steel. The Arsenal won five Army-Navy "E" awards for excellence in equipment production during World War II.

Until the Army reorganization of 1962, Watertown was part of the Ordnance Department. Then, the Army assigned responsibility for conventional weapons work to the Rock Island Arsenal, and Watertown took a supporting role in the Missile Command. At the same time, combining the Ordnance Materials Research Office and the Watertown Arsenal Laboratories created the Army Materials Research Agency (AMRA).

In 1964, the Secretary of Defense announced that Watertown Arsenal would be declared excess and phased out, while AMRA would continue in place. Following considerable public discussion, the Arsenal was closed in 1967. AMC consolidated structural materials R&D at AMRA and renamed it the Army Materials and Mechanics Research Center (AMMRC). In transition to LABCOM in 1985, AMMRC was renamed the Materials Technology Laboratory to highlight its intensified focus on the development of new materials.

component of the DMR. The initial concept of a centralized Army "corporate" laboratory arose from this task force, and in the fall of 1989, the "Lab 21" study was chartered to flesh out this idea. The ARL or Combat Materiel Research Laboratory (CMRL) construction continued to evolve during FY 90, emerging as the centerpiece of the Army's LAB 21 effort. Implementation of the LAB 21 scheme was delayed, however, while another laboratory consolidation study was performed. Congress initiated another round of base closure and realignment activity, passing legislation (P.L. 101-510) establishing BRAC 91, with members nominated in January 1991. Then, in April 1991, the Department of Defense (DoD) published its recommendations to BRAC 91, adopting the consolidation proposal to realign Army laboratories and create the Army Research Laboratory. Under the scheme, the labs would be consolidated, primarily at Adelphi and Aberdeen Proving Ground, MD, and the BRAC 88 mandate would be revised, with most of MTL relocated to APG.

In its report to the President, released in July 1991, BRAC 91 endorsed the plan for laboratory restructuring but directed DoD to delay implementation until January 1992 in order to consider guidance from the Federal Advisory Commission on Consolidation and Conversion of Defense Research and Development Laboratories. Also established under Public Law 101-510, the Federal Advisory Commission was charged with recommending various means to improve the operation of the laboratories, including (1) conversion of some or all to government-owned, contractor-operated (GOCO) labs, (2) mission and/or function modification at some or all, and (3) consolidation or closure of some or all. The Advisory Commission's September 1991 report stated that "fixing the problem organically is preferable" to converting to GOCO organizations and suggested a number of steps to improve the effectiveness of the labs as "dedicated organizations free from commercial pressure." In the main, the Advisory Commission also accepted the creation of ARL, stating that proposed consolidations and realignments should begin in January 1992.

vas also in a transitional phase at this time.

The leadership of the early organization was also in a transitional phase at this time. MG Jerry C. Harrison, the commander of Laboratory Command had coordinated with AMC Headquarters and the Corps of Engineers to formulate plans and schedules to initiate construction projects to meet the requirements established by BRAC 91. After his transfer to serve as Army's Chief of Legislative Liaison, Harrison was succeeded in January 1992 by MG Patrick J. Kelly, who facilitated coordination of Harrison's plans. However, Kelly retired later that year, and on October 1, 1992, Richard Vitali, the former LABCOM Director of Corporate Laboratories (DCL) became the Acting Director of ARL.

The change of leadership was significant because it represented an exception to the implementation plan submitted to the Assistant Secretary of the Army for Research, Development and Acquisition ASA(RDA) in a March 13, 1992 memorandum and approved in the December 1992 Implementation Plan. The plan authorized a major general as commander, along with a civilian technical director, with the commander reporting directly to the AMC Commanding General. However, the Assistant Secretary stipulated that the new organization would have a civilian director as its Chief Executive and a general officer as Deputy. The rationale was that a research organization should be led by a civilian scientist/engineer with significant credentials in the technical community and who would not be subject to mandatory rotation every two to three years. The revised Implementation Plan of July 1992 provided the impetus for the selection of a chief executive no later than 1 October 1992. Therefore, ARL was activated with a civilian Acting Director and a colonel as Deputy. Orders establishing ARL (provisional), dated July 23, 1992, provided operational control of LABCOM, the seven corporate laboratories, the LABCOM Installation Support Activity, and the Special Technology Offices, as well as those elements transferring into the new laboratory. The activation ceremony was held at Adelphi on October 2, and permanent orders organizing ARL were published on November 2, 1992.

ARL Laboratories:

Human Engineering Laboratory

The Human Engineering Laboratory (HEL) was formed in 1952 to assist in the development of engineering designs. A 1953 Ordnance Corps Bulletin set the path, emphasizing that Army equipment had to be designed so human operators could use it in the best possible way. Thus, the capabilities and limitations of humans had to be given thorough consideration in the development of new technologies. Early studies included observations of operations under arctic and desert conditions, a study of padding for protection in military vehicles and comparisons of positions for driving tanks.

During the 1962 Army reorganization, HEL became a corporate laboratory within AMC, charged with coordinating all the human factors engineering initiatives within the Army. In 1968, HEL, BRL and other elements were combined into the Aberdeen Research and Development Center (provisional), officially established in 1969. In the new organization, each laboratory retained its own civilian technical director but shared a common commanding officer. The Center was short-lived, lasting only until 1972, when HEL again became a corporate laboratory reporting to AMC Headquarters.

In 1975, AMC agreed to a pilot project to convert the human engineering groups at its MSCs into HEL detachments. HEL also gained field office representatives at the major centers and schools of the U.S. Army Training and Doctrine Command. In 1982, HEL moved into a new building at Aberdeen, and it became part of LABCOM in 1985.

HEL helped AMC and its system design contractors develop materiel that was simple to operate and maintain. It also implemented the MANPRINT initiative to ensure that manpower, personnel, training, safety, medical and human factors engineering issues were given high priority throughout the acquisition, development, testing and fielding processes.

When ARL was activated, HEL became the Human Research and Engineering Directorate.

The challenge was to continue these efforts while establishing ARL's structure and facilities.

With activation in October 1992, Vitali, formerly the LABCOM Director of Corporate Laboratories, officially became the Acting Director of ARL, a position he held for almost one year. His mission was twofold: facilitate the organizational transition from LABCOM into ARL, and provide an atmosphere where scientists could continue their research efforts from LABCOM. Vitali had a wealth of experience in the old organization, serving as its Technical Director and eventually being named its Director of Corporate Laboratories in 1988. He had also been instrumental in forming LABCOM'S organizational structure, and came to ARL with the reputation of being able to nurture his subordinates by preparing them for their eventual levels of responsibility. Essentially, Vitali's strength was his reputation as a mentor who could provide the organization and guidance to employees being groomed for future leadership positions. These skills served Vitali and ARL well, as his tenure was a success in several areas.

First, Vitali helped facilitate an atmosphere where former LABCOM and other scientists could transition their work into ARL's new mission. The new organization encompassed research in a variety of fields, including information distribution and management technologies; human cognitive and sensory capabilities; simulation and virtual reality; nanotechnology; composites and ceramics; ultra wide-band radar; and lightweight, rechargeable power sources. The challenge was to continue these efforts while establishing ARL's structure and facilities. Among these were new facilities constructed at Adelphi, which would accommodate personnel relocating from Fort Belvoir, Fort Monmouth, and White Sands Missile Range. In addition, new facilities at APG would house the Materials Directorate, moving from Watertown, MA, as a result of recommendations by BRAC 91.

Vitali was also responsible for overseeing the formation of ARL's Board of Directors. The Board of Directors' mission was to enable contacts between ARL and its principal customers — the Research, Development, and Engineering Centers (RDECs) and AMC command, to ensure that the laboratory was fulfilling the needs requested of it. After its assembly, the Board met twice in its first year to review the research and exploratory developmental programs in light of Army needs.

The Technical Advisory Board, consisting of research leaders primarily from the National Academies of Science and Engineering, also met for the first time in 1993 and began providing critical evaluations of research programs. The TAB provided an invaluable service to ARL by giving expert, independent and unbiased reviews of the quality of the ARL technical program, something which is very difficult for a government laboratory to obtain, but which is absolutely essential for a lab if it is to

achieve world class status. The TAB also suggested improvements in the operation of the lab, assisted in evolving long-term research goals, and monitored technological advances and how they impacted ARL research.

The consolidation of LABCOM and other organizations into ARL also required a restructuring of personnel. Total consolidation was to save the Department of Defense $55 million per year, commencing in 1993. The number of civilians employed by the lab dropped from 3909 to 3576 during the year, due largely to the number of people participating in the Voluntary Early Retirement Authority (VERA) and Voluntary Separation Incentive Pay (VSIP) programs offered. A total of 225 people accepted either the early retirement or the separation incentives. But reducing personnel was not the only initiative taken during this first year; it was recognized that recruitment and retention of personnel with necessary skills and knowledge was critical to maintaining ARL's viability. In conjunction with AMC and various state and local agencies, ARL initiated a number of actions intended to reduce the effects of these relocations. Consequently, the ARL Human Resource Management Division established Transition Assistance Offices (TAOs) at Adelphi, MD, White Sands Missile Range, NM, Woodbridge, VA, and Watertown, MD. The TAOs were to provide placement and referral opportunities for employees affected by transfer of function, downsizing, reduction in force, or similar action during the transition phase.

In the midst of all of these changes, ARL scientists and engineers were responsible for performing the research that would lead to the development of those revolutionary technologies for which ARL is known today. Indeed, the list of projects tackled by ARL in its first year was a litany of exciting opportunities. Among these were the Warrior's Edge program. It involved virtual reality simulation to identify the technology needs of individual soldiers, and "Owning the Weather," a coordination of previously-existing information systems to give friendly forces the ability to see, maneuver, fight, and win in all types of weather by providing commanders and staff with advance knowledge of battlefield environmental conditions and likely effects, enabling them to select the most appropriate mix of sensors, weapons systems, and tactics.

However, the most significant of ARL's projects in its first year was to upgrade the effectiveness of U.S. fighting forces. Because of friendly-fire fatalities ("fratricide") in the recently-concluded Persian Gulf War, the then-Sensors, Signatures, Signal and Information Processing Directorate continued work on the Battlefield Combat Identification System, which would better identify both enemy targets and allies in the field. Also, the need to detect targets employing camouflage, concealment, and other deceptive techniques spurred research in ultra-wide band foliage penetrating

ARL's first year also saw immediate

Technologies developed for military use often have commercial applications as well. Technology is transferred to the civilian sector through cooperative R&D agreements for joint research, domestic and international technology transfer programs, and the Small Business and Innovative Research program.

Technology Transfer:

Hockey Sticks

In July 1992, ARL entered into a CRDA with Composite Development Corporation (CDC) to investigate a new way to make constant-cross-section, high-performance composite products. The results for the Army were low-cost launch tubes, helicopter rotor blades, bridge decks, and tent poles and, for the commercial sector, a top-of-the-line hockey stick.

CDC believed that composite materials could help make a superior hockey stick, but it did not have the capital to purchase an assembly line to test the idea. Under the CRDA, CDC used ARL's state-of-the art equipment to test a manufacturing technique called pultrusion, where fibers spooled at one end are continuously drawn through a resin bath and then pulled into a heated die, where they are cured. The cured material was than pulled from the die in a continuous form for cutting to any desired length: here, the four feet necessary for a hockey stick. This cooperative approach allowed CDC to use Army expertise and equipment to manufacture and test a new world-class product without a large investment in equipment, while the Army furthered its research in pultrusion manufacturing techniques.

Armed with the new hockey stick that CDC and ARL developed and produced only nine months after signing the CRDA, CDC signed a multiyear contract with a major hockey stick manufacturer.

synthetic-aperture radar (FOPEN SAR). Battlefield information was also enhanced by the development of a prototype system, the Commander's Visualization Research Tool, which promised to give commanders real-time formatted battle information. Finally, the lethality of U.S. armaments was advanced through the development of the High-Capacity Artillery Projectile (HICAP), which represented a major milestone toward the goal of substituting composites for steel in future shells, thus permitting the weight savings to be allocated to greater payload or longer range.

While developing technology was the most significant part of ARL's mandate, its first year also saw immediate returns on the organization's work. The Clinton administration had committed U.S. forces to peacekeeping and humanitarian operations throughout the world, and AMC technologists were providing rapid technology support to U.S. troops in Southwest Asia, Somalia, and Macedonia. Among these technologies were infrared lights, thermal tape, and Kevlar blankets, all of which were vital in fitting and protecting American soldiers abroad.

One of the most important of ARL's first year initiatives was the establishment of cooperative programs with various academic, industrial, and international institutions, most of which are still in place today. ARL fostered relationships in academia, including the Massachusetts Institute of Technology (MIT), University of Delaware, University of Maryland, University of Massachusetts, New Mexico State University, University of Texas El Paso, and the University of Arizona. Further, it expanded partnerships through the Small Business Innovative Research Program (SBIR) and pursued stronger ties with historically black and minority institutions (HBCU/MIs). Educational Partner Agreements were signed with Southern University, Hampton University (July 1993), and University of Texas at El Paso (November 1993). In addition, in April 1993, ARL signed a memorandum of agreement with the U.S. Military Academy to establish an ARL-sponsored Mathematical Sciences Center of Excellence at the Academy.

returns on the organization's work.

Furthermore, the AMC tech base community conducted an active program in pursuit of cooperative projects with several of our foreign allies. Much of the international program was accomplished through working groups and reciprocal visits, in coordination with the AMC Office for International Cooperative Programs. ARL's bilateral program centered on three senior-level working groups in Israel, France and Germany, with reciprocal meetings conducted with Japan and Korea. In late September and early October of 1992, AMC technologists hosted the third visit of the Japanese Armament Study Team. In 1993, an international robotics investment strategy was coordinated, and a technology assessment of electric power sources began. An Engineers and Scientists Exchange Program was initiated, with seven ARL scientists spending 60-90 days in labs in either France, Germany, or the United Kingdom. Under the Nunn Program, the lab proposed a project on lithium batteries with France and another on machine translation with Japan. The U.S.-Israeli Technology Working Group completed four technology assessments, in ballistics, human research, acoustics, and robotics.

ARL had accomplished much in its first year of operations. The foundation of what would eventually be five directorates had been established; employees had moved into existing facilities and plans for future facilities were being implemented; research projects from LABCOM had been integrated into the organization; and partnerships with extragovernmental entities were formed. However, much had to be done that could not possibly be accomplished in the scope of one year. Now that the various pieces were in place, the need to coordinate more effectively between them remained. And while technology continued to be developed by the new organization, long-range plans for basic research had to be formulated. Finally, ARL had to adjust to the ever-changing demands of the modern battlefield. All of these goals and more would be addressed by ARL's first Director, John Lyons.

Unit Insignia

Heraldic Description: A gold-color metal and enamel device one and one-eighth inches in height overall, consisting of a blue disc bearing a white triangle issuing from the top, one point to the base with indented sides; the disc encircled by a gold band with "Technology to Win" in black letters inscribed in the base; overall at the top a gold pyramid in perspective, emitting from its point a white starburst of eight rays.

Symbolism: The white wedge or triangle device, adapted from the Army Material Command (AMC) shoulder sleeve insignia, indicates that the organization is an AMC major subordinate command. The pyramid represents basic science and mathematics and refers to the technology involved in mission accomplishment. The blocks of the pyramid denote the major elements of the command and their functions as part of and supporting the whole, and the two faces or aspects suggest the execution of both laboratory and headquarters functions. The starburst suggests knowledge and light. Gold connotes value and excellence, and the band circling the whole suggests central control, as well as unity and strength of purpose.

Section 2: Building ARL, 1993-1998

As the presidential election of 1992 approached, it was clear that the world had changed. The Cold War was over. America awoke from its almost 50-year arms race with the Soviet Union and began addressing problems at home. Realization set in that a federal government that had grown in every administration since President Kennedy's had not completely addressed the needs of American citizens. Suddenly, Americans wanted not more government, but less; more efficient agencies, not more bureaucracy. While politicians from both parties had expressed these sentiments for several years, the issue became one of the central themes of Bill Clinton's presidential campaign in 1992. In that year, he remarked:

> We can no longer afford to pay more for — and get less from our government. The answer for every problem cannot always be another program or more money. It is time to radically change the way government operates — to shift from top-down bureaucracy to entrepreneurial government that empowers citizens and communities to change our country from the bottom up. We must reward the people and ideas that work and get rid of those that don't.

"Reinventing government," or the Clinton administration's plan to consolidate the federal workplace and make it more efficient and effective, would affect the entire Department of Defense. With the threat of the Soviet Union gone, and the United States standing as the lone superpower after the Persian Gulf war, the military budget became one of the first items discussed under plans to reshape the federal government. As these directives were being implemented, Dr. John Lyons assumed the helm as ARL Director. The years of his tenure would involve accommodating the consolidation initiatives while continuing to build ARL's organizational structure and heightening its reputation. It was at times a delicate balance to maintain.

Dr. John Lyons, who had formerly served as Director of the National Institute of Standards and Technology (NIST), became ARL Director on September 14, 1993. A former chemist, Lyons had worked his way up in the National Bureau of Standards, serving as director of its National Engineering Laboratory for 13 years. After NBS transitioned into the National Institute of Standards and Technology, Lyons served

John Lyons served as Director of ARL from 1993-1998.

as director of the entire organization. Lyons was also well-known as a scholar, having published four books and over sixty papers. Lyons had also been a member of the Federal Advisory Commission on Consolidation and Conversion of Defense Research and Development Laboratories that had laid out the original parameters for creating an ARL so he was well familiar with the vision of the organization.

Lyons quickly established a reputation as a leader who wanted to understand how the various components of ARL worked. After reviewing some of the technology ARL and LABCOM had already produced (he even went so far as to test-drive the Abrams tank and test its cannon at the Aberdeen site), Lyons visited several of the directorates and became convinced that the laboratories were confronted with several serious difficulties in their operating environments that threatened their ability to perform. Moving swiftly to adapt suggestions as well as opportunities provided by President Clinton's administrative campaign to reinvent government, Lyons requested assistance from AMC in securing program reforms that included a modified and flexible personnel system, a consolidated funding authority, further emphasis on basic research, and opening the laboratories up to facilitate increased numbers of staff exchanges. Among the management innovations that Lyons undertook was to become a National Reinvention Laboratory under the National Partnership for Reinventing Government under which ARL won four Hammer Awards. Lyons also volunteered ARL to be a pilot project under the Government Performance and Results Act of 1993 (P.L. 103-62), the only pilot of more than eighty across the government to represent the R&D sector. Under this program ARL developed new and innovative approaches to strategic planning and performance evaluation as applied to basic research. These techniques still provide a benchmark for both public and private technology organiza-

ARL Laboratories:

Electronics Technology and Devices Laboratory

The Electronics Technology and Devices Laboratory (ETDL) traces its origins to the Signal Corps Laboratories at Fort Monmouth, NJ. During the 1920s, Fort Monmouth emerged as the Army's center for communications training and research.

In the 1950s, the Electronics Components Research Laboratory, as ETDL was then known, moved into expanded facilities at the new Hexagon Building in the Camp Wood Area. With emergence of the semiconductor industry setting the stage for major displacement of conventional tubes and electronic devices by transistors and miniature parts, the laboratory established a new Solid State Division to support the solid circuit or integrated circuit concepts.

With the Army reorganization of 1962, the renamed U.S. Army Electronics Research and Development Laboratory joined AMC as an element of ECOM. In a 1965 restructuring, ECOM organized seven separate R&D activities along functional lines, among them the Electronic Components Laboratory and the Institute for Exploratory Research. In 1971, these two activities were consolidated to form ETDL. In 1978, ETDL was placed in ERADCOM, subsequently becoming part of LABCOM in 1985.

For LABCOM, ETDL advanced the technology base in electronic devices and materials. It managed the Army program in Very High Speed Integrated Circuits (VHSIC), with the primary objective of accelerating the introduction of advanced integrated circuit technology into weapons systems. ETDL also operated and managed the Army's new Pulse Power Center at Fort Monmouth that provided the defense establishment with expanded capability for development, test and evaluation of high energy/high power components, which were important elements in the Strategic Defense Initiative.

With the realignment into ARL, ETDL provided most of the Electronics and Power Sources Directorate. In 1995, the major portion became the Physical Sciences Directorate (PSD), slated to move into new facilities at Adelphi. In 1996, most of PSD migrated into the Sensors and Electron Devices Directorate.

tions to this day.

However, another study of DoD management provided the impetus to consider some radical new constructs. In December 1993, the Under Secretary of Defense chartered a Task Force on Defense Laboratory Management that was chaired by GEN Paul F. Gorman in the spring of 1994. A new proposal emerged that addressed digital communication issues and placed ARL construction programs back in motion. This significant shift in ARL's mission during Lyons' tenure resulted from both the drive to consolidate the federal government and the Army Chief of Staff's aim to "digitize the battlefield." As Army strategists and technologists approached the 21st Century, they realized a revolution in warfare was coming. The late twentieth century explosion in the information sciences and the ever-increasing speed and ease in which information could be gathered and distributed had poised information technology to become a paramount weapon on the future battlefield. Success there, however, depended on the Army's ability to apply existing and emerging information technologies to provide commanders with complete, accurate and detailed information about battlefield events as they happened. As GEN Gordon Sullivan, the Army Chief of Staff from 1991-1995 remarked, "winning the information battle is the key to decisive victory."

Operations Just Cause and Desert Storm had provided a glimpse of the future battlefield. America's military was able to successfully conduct swift, simultaneous and synchronized attacks on numerous objectives at night, using forces stationed in various locations. This application of modern technologies, organization and doctrine achieved decisive results that would not have been possible just a few years earlier. However, the demand for research never plateaus, and military leaders knew that the technology and tactics that won in Panama and Desert Storm wouldn't win the battles of the twenty-first century. Consequently, GEN Sullivan made winning the information battle the first objective of the Army's

ARL Laboratories:

Atmospheric Sciences Laboratory

Located in the historic Tularosa Basin at White Sands Missile Range (WSMR), NM, the Atmospheric Sciences Laboratory (ASL) was founded shortly before World War II. Meteorological research for the Army began in the 1920s when scientists began evaluating meteorological phenomena related to artillery. By 1956, there were 15 meteorological support teams located at test facilities throughout the U.S. Headquarters was located at Fort Huachuca, AZ, under the direction of the Signal Corps at Fort Monmouth, NJ.

During the 1962 Army reorganization, responsibility for meteorological R&D was assigned to the U.S. Army Electronics Command (ECOM), which later established ASL at Fort Monmouth. In June 1969, as a step to correct some of the geographical and organizational fragmentation, ECOM consolidated meteorological efforts by transferring the headquarters of ASL from Fort Monmouth to WSMR. Shortly thereafter, the meteorological activities at Fort Huachuca were also moved to WSMR.

With the establishment of LABCOM in 1985, ASL became part of the new command, but only after some discussion. AMC considered abolishing ASL but concluded that ASL's work was valuable to the Army. ASL gave the Army expertise in the atmospheric sciences, providing developers with assessments of atmospheric effects on proposed weapons and concepts. ASL also provided atmospheric and meteorological technology, sensors and systems to support artillery, chemical, aviation, armor and intelligence activities. Linking these sensors and systems provided weather intelligence for combat operations.

When ARL was established in 1992, ASL transitioned into the Battlefield Environment Directorate (BED). In 1995, the BED Atmospheric Analysis and Assessment team moved to the Survivability/Lethality Analysis Directorate (SLAD), expanding SLAD's threat-effects analysis mission. In 1996, the remaining bulk of BED was folded into the Computation and Information Science Technology Directorate.

Opposite: ARL facilities in Langley, VA

ARL Laboratories:

Vulnerability Assessment Laboratory

The Vulnerability Assessment Laboratory (VAL) began in 1951 as Field Station I of the Signal Corps Engineering Laboratory. After several name changes, Field Station I eventually became the Signal Missile Support Agency (SMSA).

SMSA was a component of the Electronics Research and Development Activity. In the 1962 Army reorganization, it became part of ECOM, conducting research in missile electronic warfare, missile vulnerability, missile surveillance and environmental sciences. It also coordinated the missile electronic countermeasures effort of the Army.

In the mid-1960s, the element was renamed the Missile Electronic Warfare Division and assigned to the newly organized Electronic Warfare Laboratory (EWL). After another name change to the Missile Electronic Warfare Technical Area, it became the Office of Missile Electronic Warfare (OMEW). ERADCOM was then established, with EWL/OMEW as a major unit.

In 1985, the Commander of ERADCOM/LABCOM recommended including OMEW, which had been renamed the Vulnerability Assessment Laboratory (VAL), within the new command. VAL was tasked with providing independent assessments of the electronic warfare vulnerability of Army weapons and communications-electronics systems and recommending electronic countermeasures for reducing or eliminating those vulnerabilities. The VAL mission covered air defense, close combat and fire support, communications-electronics and advanced concepts. VAL was also charged with determining the vulnerability of threat missile systems.

VAL transitioned into the Survivability/Lethality Analysis Directorate with the creation of ARL.

modernization strategy for Force XXI. The foundation for winning the information battle was successfully applying information technology throughout the battle space.

ARL worked with the Training and Doctrine Command (TRADOC), the Communications-Electronics Command (CECOM), AMC's research, development and engineering centers (RDECs) and other Army organizations to meet GEN Sullivan's mandate to digitize the battlefield. As "the architect of the future," it was important for TRADOC to understand the emerging technologies that ARL and the RDECs were pursuing. TRADOC would be able to anticipate the impact that the technology will have on doctrine and, at the same time, ensure that evolving operational concepts for the digitized battlefield were supported by ARL's research program. The foundation to this partnership was "Futures Concepting," a TRADOC-ARL initiative designed to bring physical and military scientists together to simultaneously develop future technology and doctrine, thereby eliminating any gap. In this way, when a technology is ready for battlefield application, so is the doctrine.

However, closing the gap would not be easy; many challenges had to be overcome. Primary among them was the divide that had opened between commercial and military technology. New information technologies were being developed rapidly for commercial applications such as hand-held computers, cellular telephones, direct-broadcast television and wireless computing with new generations of devices emerging every few years priced for mass-market applications. The challenge was for the Army to provide a small, affordable, deployable system for on-the-move collaborative planning and situational awareness that was based on commercial technology and required little infrastructure. It also had to be compatible with systems currently in the Army inventory, yet provide a way of eventually moving beyond those systems.

Technical change has always led military doctrine. However, history has shown that an army that can apply evolving tech-

nical capability to the battlefield gains a tremendous advantage. In these early years of ARL, the consensus was that information technology would drive the next revolution in military doctrine. On the digitized battlefield, the goal was for computers to carry most of the routine load of the commander at all levels of command. In turn, the commander would have access to near perfect information on the battlefield and have a war gaming capability that, similar to a chess program, would enable him to evaluate in real time multiple courses of action to support his selection of the best one. Major advances in information technology had been made in the commercial world, but that technology was developed to operate in relatively benign conditions. The hostile environment of the battlefield was much different. Combat information must be gathered by automated sensors providing near perfect sensing of battlefield events. That information must be moved through and around a hostile battlefield environment under conditions of enemy jamming, deception and high noise with mobile nodes vulnerable to destruction. The raw information must be turned into useful knowledge and then presented in a format that can be easily and quickly understood by commanders and their troops. All of this must be done in real time and as inexpensively as possible. Since the Lyons tenure, ARL's task has been to supply the scientific support to the Army as it strives to close the gap between military and commercial technology permanently while ensuring that future technology and doctrine are developed in tandem.

Concurrently, the downsizing of DoD, coupled with the explosion in information technology, demanded a new approach in laboratory operations. It required ARL to become smaller while still providing state-of-the-art technology for military personnel. The end result, a federated laboratory, was a unique entity within the Department of Defense. It drew upon the best of the public and private sectors to produce the research and technology needed for present and future Army land warfare systems. The basic construct of the Federated Laboratory (FedLab) was to continue strong in-house involvement to meet Army-unique requirements where there was little external expertise, or market, for the technologies; and the forging of direct associations with industry and university laboratories with recognized competencies in specific technology areas where the centers of expertise were definitely outside of the government and the potential of the technologies had a much broader application. FedLab eventually resulted in a virtual ARL that was distributed across the nation and one third larger than ARL's actual size. Its program would be integrated into the ARL program in an open configuration, with large exchanges of staff in both directions. Included in the structure were two existing university centers of excellence that previously had reported to the Army Research

Opposite: The Rodman Materials Research Laboratory at Aberdeen Proving Ground, MD was dedicated in July 1997.

Recent Technology:

New training methods increase mine detection results

Sometimes, how you do something makes all the difference. ARL working with Carnegie Mellon University has improved the probability of detection of land mines with low metal content using the Army's current handheld mine detector by almost 80 percent.

Tests using the detector and soldiers employing standard Army detection techniques revealed that the typical detection rate was well below 20 percent. A detailed study was made of how expert deminers use the same detectors to find nearly 100 percent of the same types of mines. A specific training regimen was developed to transfer the specific skills used by the experts to soldiers as was a training site that could efficiently enable soldiers to develop the required skills and could be practically constructed by field units.

Results of the new training program demonstrated enormous increases in probability of detection in relatively little training time. Repeatedly, tests have shown increases in probability of detection from less than 20% using standard techniques to 75% (less than one hour of training) to 98% (about 15 hours of training) using the expert techniques.

Much of this research that has increased soldier performance with the current detector will also apply to the Handheld Standoff Mine Detector System now under development.

Office (ARO): the Army High-Performance Computing Research Center (AHPCRC) at the University of Minnesota and the Information Sciences Center at Clark Atlanta; and the Institute for Advanced Technology at the University of Texas, a Federally-Funded Research and Development Center (FFRDC) that had formerly reported to the Armament Research, Development, and Engineering Center (ARDEC).

In July 1994, ARL was granted authority by DA to enter into research cooperative agreements. They were different from contracts because they were not governed by the rigid requirements of the Federal Acquisition Regulations. The use of these instruments played a key role in fiscal year (FY) 95 plans to implement the concept. Cooperative agreements made possible a close and very flexible working relationship between ARL and the recipients of the agreements; influenced the exchange of research personnel to best use available facilities; and established an environment for the exchange of scientific ideas and joint research that supported Army requirements as well as commercialization of research products. The cooperative agreements provided substantial Army programmatic involvement through management committees, which evaluated and set directions for future research objectives.

In December 1994, ARL issued a Broad Agency Announcement (BAA) to the private sector. It called upon industry and academia to assemble "consortia" around several technology areas that were deemed critical to GEN Sullivan's directive to "digitize the battlefield." The BAA required a consortium to be made up of at least one industry partner that would be the lead organization, one major research university, and one Historically Black College or University or Minority Institution (HBCU/MI). The results of the BAA solicitation were overwhelming. ARL received bid packages from 38 consortia made up of all the leading technology centers in the private sector. After a rigorous selection process three consortia comprising a total of 27 partners in 17 states were selected, one each in the areas of Advanced

Sensors, Telecommunications/Information Distribution, and Advanced/Interactive Displays, and $122 million was budgeted for them over the five year period beginning in 1996.

Over the five year period FedLab was an outstanding success. Some of the indicators of this are:

- Over 400 members of our partners' staffs augmented 1,250 ARL scientists and engineers,
- Over 40 individuals participated in rotational assignments,
- Over 600 papers were published in refereed journals, and
- ARL was able to leverage over eleven million additional dollars of our partners' internal funds towards FedLab-related activities

The two most important outcomes, however, were the many products that were delivered from the FedLab activity to ARL's customers, and the fact that ARL was able to amplify its own technical competence through its association with this array of world class partners. This enabled ARL to be able to play the critical role of "smart buyer" for the Army's technology needs. ARL was specifically called out for recognition by the Senate Armed Services Committee for this highly innovative approach to public-private partnering: "The Army's initiative to create an open, federated laboratory system is an innovative and forward-thinking approach. The committee supports the competitive selection of laboratories from industry and academia to work with the Army Research Laboratory to meet Army research needs across a wide range of technologies."*

Transitions

The move toward the digital battlefield and the establishment of FedLab set off a flurry of consolidation within ARL's directorates. The process began in April 1995, when an ARL center of excellence in digital communications sciences was developed. The former Sensors, Signal and Information Processing Directorate (S3I) was separated into the new Sensors Directorate (SEN) and the Information Science and Technology (IST) Directorate. The SEN Directorate, along with most of the S3I and three branches of the Electronic and Power Sources Directorate (EPSD) located at Fort Belvoir, focused its activities on infrared focal plane arrays, microwave and millimeter-wave radar, optics, and acoustic sensors, as well as advanced sensor concepts. The Information Processing Branch of S3I, the Military Computer Science Branch of the Advanced Computational and Infrormation Sciences Directorate

* National Defense Authorization Act for FY 1995, SASC Report, June 14, 1994

Opposite: The Acoustic/Electro-Optic Propagation Research Site opened at the Blossom Point Research Facility at Blossom Point, MD in May 1998.

Technologies developed for military use often have commercial applications as well. Technology is transferred to the civilian sector through cooperative R&D agreements for joint research, domestic and international technology transfer programs, and through the Small Business and Innovative Research program.

Technology Transfer:

Acoustic Physiological Sensor

Sometimes, good technology results from simple ideas. An ARL engineer was shopping for a new bed. Sitting on a waterbed he noticed that motion as any point on the bed caused the entire bed to respond. This simple observation led him to develop an acoustic sensor that provides excellent acoustic coupling of heart and breath sounds; collects information concerning heart, lungs, and digestive tract functions; and detects changes in voice or sleep patterns, motor activity, and mobility. The concept was to insert a hydrophone into a liquid-filled blatter configured as a flat pad and placed in contact with the human body. Since the body is mostly water, the pad acts as a fluid extension of the body and forms an acoustic conduit to the hydrophone.

Vestaguard Corp. and Personal Electronics Devices, Inc. (PED) licensed the invention. Vestaguard will develop a SIDS (Sudden Infant Death Syndrome) and apnea monitor and will continue to develop the technology through a Cooperative Research and Development Agreement (CRDA). PED will market the device to monitor physiological readings for exercise purposes.

SIDS affects newborn infants who stop breathing and die for no apparent reason. A monitor can alert parents to the situation and help stimulate the infant to begin breathing again. Apnea is a condition in which affected people stop breathing for varying periods of time while asleep.

The Army is developing the sensor to be worn by soldiers to measure their vital signs during training or in combat.

(ACIS), and some personnel from EPSD and the Battlefield Environment Directorate (BED), formed the IST Directorate with areas of technical expertise in sensor and data fusion, display integration, knowledge-based reasoning, high-performance wireless networks, automated information distribution, data and image compression, adaptive communications and networks, secure exchange, and architectures research.

Meanwhile, most of EPSD became the Physical Sciences Directorate (PSD), and focused on pervasive 21st century technologies, including solid state physics, nanotechnology, chemical science and technology, biological sciences, and manufacturing science. ACIS transitioned into the Advanced Simulation and High-Performance Computing Directorate (ASHPC). ASHPC concentrated on advanced distributed-simulation technology, software engineering, artificial intelligence and expert systems, real-time language translation, supercomputing, distributed and parallel computing, and wide-bandwidth networks. The BED Atmospheric Analysis and Assessment team was moved to the Survivability/Lethality Analysis Directorate (SLAD), expanding SLAD's threat-effects analysis mission and consolidating all of the laboratory's 6.5 mission funds in one directorate. The restructured BED concentrated on signature distortions, atmospheric modeling, electromagnetic energy propagation, remote detection and identification of chemical and biological agents, weather analysis aids, weather measuring techniques, and land battlefield modeling. Finally, the Human Research and Engineering Directorate (HRED) reorganized internally to form a Soldier Information Division to support the laboratory's emphasis on digitalization and communications science.

While these changes occurred, the ASA(RDA) commissioned a study that examined options with regard to the future of ARL. The study was a response to recommendations in an Umbrella Functional Area Analysis (FAA) conducted by the Deputy Chief of Staff for Operations, in light of changing needs, program transitions, and funding reductions. ARL had

already achieved a 41 percent reduction in personnel since 1989 and had undertaken a significant consolidation effort in compliance with BRAC 91, at a cost of approximately $328M over the 1991-1997 timeframe. Nevertheless, the report recommended that ARL should further decrease its number of directorates while focusing programs and achieving maximum overhead savings. This would sharpen technical focus and decrease overhead by focusing ARL on Armor and Armament, Battlefield Information Science, Sensors and Electronic Devices, Human Research and Engineering, and Survivability Analysis, all of which would have the greatest potential in support of Army long-term readiness with the lowest implementation costs and difficulties.

Therefore, ARL began FY 97 with five technical directorates and two centers, and a Chief of Staff support function. The Weapons and Materials Research Directorate (WMRD) combined materials and weapons research to position ARL more effectively to support development of future land combat systems. The ISTD addressed a broad spectrum of research aimed at the digitalized battlefield beyond Force XXI. The Sensors and Electron Devices Directorate (SEDD) developed technology for advanced solid-state components and the state-of-the-art sensor systems to provide battlefield awareness and targeting. HRED conducted a broad-based program of scientific research and technology directed toward optimizing soldier performance and soldier-machine interactions in order to maximize battlefield effectiveness, while ensuring that soldier performance requirements were adequately considered in technology development and system designs. SLAD provided technical support in the analyses of the survivability and lethality of Army technologies and systems in the full spectrum of battlefield threats and environments. The Vehicle Technology Center (VTC) addressed propulsion and structure technologies for both air and ground vehicles, while maintaining existing relationships with NASA. Finally, the Corporate Information and Computing center (CICC) focused its efforts on ARL's business and high-performance computing assets, and served as the management vehicle for the DoD Major Shared/Resource Center (MSRC) and the AHPCRC.

The five directorates and two centers received a major addition in 1998, when the Army Research Office joined the ARL team. The shift went hand-in-hand with Lyons' emphasis on basic, or 6.1, research. Just after assuming the ARL helm, Lyons indicated that "any large laboratory like this needs strong scientific underpinnings. If you don't have that as a foundation, then you can't do the applied work." ARO had existed separate from ARL and its predecessors for almost 50 years, and the vast

Technologies developed for military use often have commercial applications as well. Technology is transferred to the civilian sector through cooperative R&D agreements for joint research, domestic and international technology transfer programs, and the Small Business and Innovative Research program.

Technology Transfer:

Dielectric Resonance Oscillator (DRO)

In a constant quest to make electronic devices smaller and more effective, Army research has improved the device that creates steady single-frequency signals for a number of systems. Existing crystal oscillators, when stimulated with electricity, resonate at a fixed frequency. But crystals often produce other than the desired single frequency (called noise), and cannot produce the higher frequencies required by modern communication systems without increasing the noise in relation to the signal. Compensating for ever-increasing noise at higher frequencies while maintaining a fixed temperature range takes complex circuitry. This makes the crystal signal source larger, heavier, and less reliable.

A new type of device, the dielectric resonance oscillator (DRO), relies not on a vibrating crystal but on the vibrating molecules of a ceramic puck to provide a stable, virtually noise-free, very high-frequency signal at temperatures ranging from -100deg F to 100deg F. Perfected at ARL, the small and rugged DRO (half the size of existing oscillators) produces an extremely pure signal and can be used in virtually any environment without noise reduction and temperature-control attachments.

The Special Forces saw an immediate need for this tough but small device and included it in designs for its transmitters. Under one CRDA and a patent license, DROs for an existing Navy testing device were designed.

Another small business entered into a CRDA and patent licensing arrangement with ARL to use the DRO in telecommunications devices such as cellular phone systems.

ARL's success depended heavily on the availability of...

top facilities that would enable

majority of its previous work had focused on basic research. The organization had many valuable contacts with the university community, the source of much of the invaluable basic research being done in the United States. It also had several strong ties to ARL, having established several of the "centers of excellence" that had been brought into the FedLab structure. With the Army's need to more tightly focus its basic research on future needs, the ARO Director became the ARL Deputy Director for basic research, with a charter to coordinate all 6.1 research being performed at ARL, including that of the directorates.

ARL's organizational structure was not the only development in this period. The lab was also evolving in more tangible ways. ARL's success depended heavily on the availability of top facilities that would enable future cutting-edge research. In 1996 and 1997, several of these facilities were either completed or constructed sufficiently for initial use. At APG, the Target Assembly and Storage Facility on Spesutie Island supported work on classified targets. Construction of this facility was started in January 1996 and competed in May 1996. Later installation of the high-efficiency particulate air filter in 1998 provided personnel with the specialized capability of working with heavy-metal armors, such as those using depleted uranium. In July 1997, the Rodman Materials Research Laboratory was dedicated to accommodate scientists and engineers transferred from Watertown, NY and Fort Belvoir, VA. The $76M facility was perhaps the best equipped of its kind in the world and supported a wide range of basic materials research for defense and government customers. It had begun operating a few months before its official dedication.

Construction also continued at Adelphi Laboratory Center (ALC). The High-Bay Facility was completed in February 1996 and occupied in May. It accommodated ISTD's research in atmospheric science. In October 1997, ARL dedicated the Electromagnet Research Facility. Previously known as the Scale Model Laboratory, it was designed as an electromagnetic transparent scale model experimentation facility. Personnel *future cutting-edge research.*

relocated from Woodbridge, VA used this facility for research that included ultra wideband radar and high-power microwave programs. The Adelphi site also received its own administrative building when the Della Whittaker Building officially opened in August of 1997. Finally, during this period, construction commenced on what would be the Zahl Physical Sciences Facility. The $73.9M project would eventually house SEDD, which was transferred from Fort Monmouth, NJ and Fort Belvoir, VA. The facility also included a $6.7M Military Construction Army project for CICC. This research and development computer center consolidated CICC at ALC and provided a central connecting point for ALC to tie the high-performance and simulation computers at APG. As a result of all of this construction, the Woodbridge Research Facility was closed in September 1994 and the ARL-Watertown, NY site was closed on September 29, 1995.

During this period, there were also major innovations in the management of ARL's workforce. In the FY 95 Defense Authorization Act, Congress empowered the National Performance Review Science and Technology Reinvention of Laboratories to design alternative civilian personnel systems. The purpose was to enhance the effectiveness of DoD laboratories by allowing greater managerial control over personnel functions and, at the same time, expanding the opportunities available to employees through a more responsive and flexible personnel system. For the Army, the personnel demonstration involved almost 8,000 civilian employees in four science and technology organizations, including ARL, the Missile Research, Development, and Engineering Center (RDEC), the Corps of Engineers Waterways Experiment Station, and the laboratories of the Medical Research and Materiel Command. In January 1995, Lyons organized an executive steering committee that drafted plans to implement a revised personnel management system that included broad pay bands, pay for performance, more generic job descriptions, and automated job grading. The system would coincide with the consolidation of ARL directorates. The Operations Directorate was

Technology Transfer:

What a Radio Can Do

Under a 1992 SBIR contract with Iterated Systems Inc., ARL sought proposals to solve the problem of using radio equipment to send and receive map images and motion-video pictures without losing or corrupting the data.

Using a mathematical concept called fractal image compression, a multi-user Army team and Iterated Systems began with military maps. These contain a very large amount of information, from the elevation and slope of surfaces to the disposition of friendly and enemy troops.

Having learned how to compress the data representing a map to 1/70th of its normal size, send it through military radios, and display it with no perceptible degradation, the team completed a more challenging task-communicating and expanding motion-video data they had compressed from 1/2 to 1/700th of its normal size. The result was a software system that compresses billions of bits of information, packages them to avoid loss when transmitted over standard radios subject to jamming, and then expands the data —- all with no loss of detail.

This advance in data compression, transmission, and expansion permitted commanders far from the battle to see exactly what is happening in real time, make decisions based on facts collected from the various sources available, and send back to commanders at the front a map image marked with all the facts-all this over radios the Army already uses every day.

Iterated Systems also fielded two commercially available software systems; one that stores, retrieves, and presents large digital maps that users can link to libraries of still and video pictures as well as audio information. It is commercially available in interactive multimedia encyclopedias on CD-ROMs.

The other system compresses and expands video images that make real-time video-conference transmission over conventional phone lines, portable phones, and radio channels possible.

Opposite: The Woodbridge Research Facility in Virginia was transferred to the U.S. Fish & Wildlife Service in June 1998, after nearly 50 years of Army control.

scheduled for reassignment under the Chief of Staff, and the position of Chief of Staff became a Colonel who reported through the Deputy Director to the Director. ARL planned the implementation of the new Personnel Demonstration System for all eligible General Schedule employees in 1998. Effective October 8, 1997, as part of the general DoD restructuring, most operations of the ALC Personnel Office were centralized in the Northeast Regional Civilian Personnel Operations Center at APG. Civilian Personnel Advisory Centers at ALC and APG gave on-site advice and assistance to managers and employees. Rationalization provided a new methodology of doing business and resulted in a staffing reduction of more than 50 percent within the ARL civilian personnel community. ARL also stepped up its efforts in minority hiring at this time, as Lyons established a Minorities Committee in early 1996 to address workplace issues and examine the recruitment and hiring processes. It would later transition into a wider-ranging diversity board in late 1998.

Army After Next

The FedLab concept had already emphasized the importance of reconciling the Army's digital capability with technologies developed for the commercial sector. However, the paradigm for technological development shifted once again in the later years of the Lyons regime. This occurred through the development of the Army After Next (AAN) concept. The principle of AAN was to augment ARL's shorter term technological advances with longer term goals that investigated the needs of the Army ten years hence. This goal would require an unprecedented advance in information systems, sensors, weapons, and radically new concepts for logistics support. As the Army's corporate laboratory, ARL would play a key role assuring that the technologies to win would be available and inserted in the next and future generations of combat and support systems. AAN provided a unique opportunity to focus ARL's research program on critical operational requirements. Even closer coordination with TRADOC and the entire community was needed to identify and ensure that new initiatives supported a smaller, lighter, faster, and more lethal force that was envisioned for AAN with specific emphasis on knowledge and speed.

In conjunction with AAN, ARL reformulated its strategic planning process to focus on several major long range problems that the Army After Next would face. This set of "Grand Challenges" represents a subset of those strategic problems to which ARL could bring to bear its world class technology competence. The five Grand Challenges about which ARL restructured its long range program planning are:

- Survivable systems with lethality overmatch in complex terrains.

- Lighter, faster, more fuel efficient mobile platforms to reduce the logistics tail and enhance deployability
- Provide commanders unprecedented real-time situation awareness of the battlefield
- Significantly improve the battlefield soldier's ability to absorb information and make decisions
- Assure information dominance in diverse operating conditions and threats

These technologies will be principal enablers of the AAN battlefield and it is essential for AMC and the Army to maintain a vigorous investment in basic and applied research to meet the needs of tomorrow's soldiers.

Fortunately, as demonstrated by some of the technology already being developed, ARL was well on its way to fulfilling the needs of AAN. The Lyons tenure saw significant accomplishments by ARL scientists in such diverse areas as robotics, battlefield visualization, and live-fire prediction and assessment. All of this was achieved while ARL provided support to soldiers deployed in Somalia, Haiti, Bosnia and other areas around the world. Perhaps the biggest technological triumph of this period occurred in December 1994, with the successful proof-of-principle demonstration of the GPS registration fuze for artillery rounds. GPS, or Global Positioning System, had already been in use for a variety of military technologies. The GPS technology, a joint service program led by the Air Force, provided accurate, continuous, all-weather, common-grid, worldwide navigation, positioning, velocity and timing data to land, sea, air, and space-based users. Now this tracking system could be utilized to determine the position of a fired round and whether that round had hit its intended target – eliminating the necessity of human verification of destroyed targets. GEN Sullivan said of this work: "Think about what this could mean within the larger picture...we may need only 1/3 as many rounds to defeat a target. This means fewer ammunition plants, fewer ships, fewer trucks, fewer truck drivers, fewer mechnics and more infantrymen, more military police. ...This is not gimmickry; this is real power."*

There were two other breakthroughs in information technology in this period. The first was the completion of the Integrated Meteorological System (IMETS) software, which uses atmospheric data to give weather forecasts for specific areas of the battlefield. IST developments also assisted soldiers in Bosnia, through development of the prototype Forward Area Language Converter (FALCon) systems to help evalu-

* General Gordon R. Sullivan, CSA, Remarks at AUSA Winter Symposium, Equipping Force XXI, Orlando, 24 Jan 1995

Opposite: The White Sands Missile Range in New Mexico continues to be an integral part of ARL's research efforts.

ate documents written in Serbian or Croatian. FALCon helps the user with no foreign language training to convert a foreign language document into an approximate English translation, enabling frontline soldiers to assess the military significance of documents obtained in the field and decide whether to pass the items to a linguist for full translation. Such technology will also be helpful to the current war on terrorism as the U.S. military finds or intercepts Al Qaeda documents. This effort influenced the development of optical character recognition software to accommodate the unique characteristics of documents in the field, while increasing the language coverage of available translation software, and incorporating an advanced multilingual retrieval capability.

ARL's technology advances were facilitated by its status as a Major Shared Resource Center, or MSRC. Recognizing the importance of computer modernization as integral to the future military, DoD initiated a High-Performance Computing Modernization Program (HPCMP) in 1994, designating ARL as one of four MSRCs in the country. Much of the upgrading process occurred throughout the Lyons tenure so that the ARL MSRC could manage several computational areas. Further, it was integrated with the other DoD MSRCs through the Defense Research and Engineering Network. These resources provided researchers with scientific visualization laboratories that enabled data interpretation and representation, and supported ARL's Army High-Performance Computing Research Center (AHPCRC).

Continuing Partnerships

ARL pursued many types of partnerships involving academic institutions and private industries to focus state-of-the-art research on Army needs. In addition to FedLab, ARL operated a number of cooperative programs and centers of excellence, as well as congressionally-mandated technology transfer programs and an extensive educational outreach program, in addition to a broad spectrum of international cooperative programs. Notable external partners included the AHPCRC at the University of Minnesota, the hypervelocity phenomena work at the Institute of Advanced Technology at the University of Austin (Texas), and the software engineering efforts at the Information Sciences Center at Clark Atlanta University. ARL also had cooperative agreements that supported microelectronics at Johns Hopkins University and the University of Maryland. Collaborative programs in materials research were conducted with Johns Hopkins University, the University of Delaware, and the Michigan Molecular Institute. ARL worked closed with several research and educational institutions that were designated as Historically Black Colleges and Universities and Minority Institutions (HBCU/MIs). In addition to the

six partners in the FedLab program (City University of New York, University of New Mexico for High Technology Materials, Howard University, North Carolina A&T, and Morgan State University), the HBCU/MI partners in AHPCRC were Florida A&M University, Clark Atlanta, Howard, and Jackson State University. Howard also had a microelectronics partnership.

The Small Business Innovative Research (SBIR) program also made great advances during this time. After its expansion in 1992, Congress increased its emphasis on dual-use opportunities and private sector commercialization. Through the SBIR program, the Army gained access to the technological advances of small, innovative firms with fewer than 500 employees. The Army set aside specific funding for high-quality research or R&D proposals of innovative concepts to solve the Army/DoD-related scientific or engineering problems, especially those concepts that had high potential for commercial use. ARL was a consistent leader in the Army SBIR program and annually averaged 20 percent of the total Army SBIR funding by FY 97. The program consisted of two phases. Awards under Phase I enabled recipients to demonstrate the feasibility of their proposals which resulted in forty-three contracts at about $100,000 each. Successful Phase I recipients applied for Phase II funding in order to enable the establishment of the proof of principle and to produce a prototype. Thirteen Phase II contracts awarded in FY 97 amounted to $750,000 for each award.

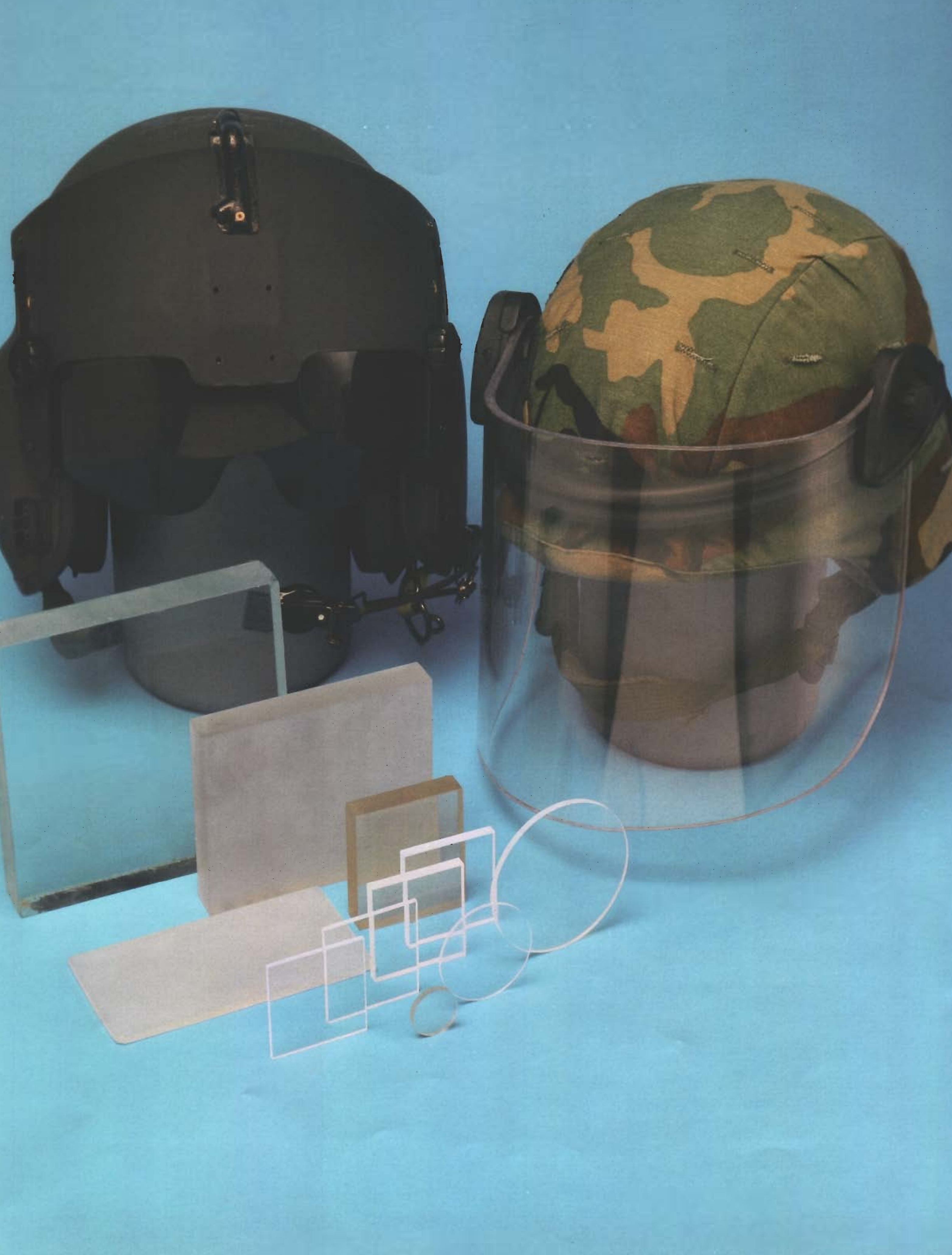
Included in SBIR as a separate program was the Small Business Technology Transfer (STTR) program created by Congress in FY94 to foster collaborations between the small business community and research institutions and to involve both in the federal R&D more effectively. ARO administered the program and ARL provided technical support and evaluated technical proposals submitted by small businesses. During FY 2000, ARL monitored six of the Phase II STTR projects valued at $600,000 each. In additional to providing support to the Objective Force, as well as support to the TRADOC Battle Laboratory, ARO addressed congressional interest in readiness and the effectiveness of U.S. Nuclear, Biological and Chemical warfare defensives.

End of an Era

A transition of ARL directorship occurred at the conclusion of FY 1998 with the retirement of Lyons. His tenure was highlighted with achievements that included the presentation of four Hammer Awards, given by Vice President Al Gore to agencies that maximized efficiency and effectiveness while following the financial parameters set by the National Partnership for Reinventing Government. These

awards were given to ARL in recognition of the development of the Personnel Demonstration Project (shared), its implementation of the FedLab initiative, its development of the Turbine Engine Diagnostic System, and the Laboratory's DoD SBIR process reform. ARL's support of TRADOC through AAN and its emphasis on information technology had helped establish its reputation as an integral part of the Army's future direction and visions. Finally, ARL was recognized by the defense community as one of the Army's centers of expertise in the computer security area. During the Lyons tenure, ARL engineers and scientists had taken great strides in establishing the state-of-the-art Army laboratory envisioned in the waning days of the Cold War. It would now be up to ARL's second director, Dr. Robert Whalin, to ensure that the organization remained on the right track as it fulfilled the goals of Army Transformation.

Laboratory efforts are instrumental in the outfitting of the modern soldier (opposite)



Section 3: Envisioning the Army of the Future, 1998-2001

1945-1990 1991 1993-1998 **1998-2001** 2001 & beyond

"Good people working together will produce more technology relevant to the soldier" was the motto espoused by Dr. Robert Whalin, ARL's second Director. Whalin came to ARL in December of 1998 and quickly set to work in making the organization, in his words, "a fully functional, seamless, smooth-running, well-oiled machine for the Army." He was selected for the position after serving as Director of the U.S. Army Corps of Engineers Waterway Experiment Station (WES) where he had more than tripled the size of its research and development and established a distinguished record. Whalin also brought with him a wealth of experience in both academia and the private sector, having served as an adjunct professor at three universities and six years in industry in southern California.

Whalin would have to steer ARL through the initiation of Army Transformation, which was announced in October 1999 by GEN Eric K. Shinseki, then Army Chief of Staff. The initiative would, in Shinseki's words, make the Army "a strategically responsive force that is dominant across the full spectrum of operations." Tranformation would be accomplished through integrating "three prongs" – the Legacy Force, or already-fielded combat systems and units, the Interim Force, and the Future Combat System (FCS). This integration would achieve the ultimate goal of Army Transformation – the new Objective Force, which would incorporate three priorities for equipment modernization: information dominance, physical agility, and lethality and survivability overmatch. Fortunately for the Army, ARL had already been developing technology with these goals in mind.

With much of ARL's organizational structure in place, Whalin now focused on more specific goals that would meet the needs of Army of the future. Among the objectives pursued during his tenure were management of the Army's basic science research grants with academia; leveraging the technology investment of the commercial sector and tapping the leading-edge expertise and facilities of universities and the private sector; and working with TRADOC and the R&D assets throughout AMC to develop enabling technologies. In addition, Whalin emphasized human

...information assurance became a necessity to prevent incorrect decisions, especially in a battlefield environment.

resources development, both in training of the workforce and aggressive minority recruitment. Finally, Whalin placed a priority on investment in technology and supported the construction of a tactical environmental simulation facility, as well as an increase in ARL's computing power.

In order to meet the challenges of Army Beyond 2010, ARL worked closely with TRADOC and the robust research and development assets of AMC. Addressing the Army needs across the total spectrum, ARL focused on initial work, which was required to deliver superior science and technology for the future Army. The process generated numerous recommendations for investment in basic research that included terrain and environment independent communications and data management, lightweight protective materials, and unmanned and robotics concepts. Some ARL technology areas identified for the Army Beyond 2010 were protection schemes for land systems, signature control, advanced materials, chemical and biological protection, alternative propellants and hybrid power systems, human and cognitive engineering, and fuel and logistics efficiencies. More specifically, ARL was interested in developing a lighter armored vehicles, providing soldiers with virtual-reality helmets, and developing weather-resistant clothing.

ARL has facilitated Army Transformation by expanding and improving upon the FedLab concept which had expired in 2001. The follow-on program was called Collaborative Technology Alliances (CTA) which continued the very successful FedLab model by advertising for self-formed consortia to submit bid packages for cooperative agreements (CAs), this time in five areas – Advanced Sensors, Advanced Decision Architectures, Communications & Networks, Power & Energy, and Robotics. On 31 May 2001, five CAs were awarded and CTA was under way, this time for a term of eight years and funded by a total of $300M of 6.1 funds. In addition, there are several other significant improvements over the former program. In addition to the 6.1 funding, there was also established an additional $300M set of five task order (IDIQ) contracts ($60M for each consortium) which would allow other sponsors to come into the program at the applied research (6.2) level and support individual efforts to enhance the probability of successfully transitioning the technology to system development programs as quickly as possible. Thus, the entire program has a potential of reaching $600M. Another new feature of CTA is the ability of other government agencies (as well as FFRDCs) to join with the private sector consortia and ARL, thus opening up the collaborative environment even further. Since CTA took over from FedLab, several other government organizations have come into the partnership bringing significant amounts of additional funding, thereby greatly enhancing the leveraging power of all the participants.

In May 2000, ISTD merged with CICD to form the Computational and Information Sciences Directorate. CISD now had four basic research areas: battlefield communications, data fusion and knowledge management, battlefield environmental work, and computational science and engineering, in addition to infrastructure support efforts. The focal point was the management of the DoD High Performance Computer Network and the High Performance Computer Center. The proliferation of computers had brought some security vulnerabilities that required intrusion detection and management administration and configuration. Further, information assurance became a necessity to prevent incorrect decisions, especially in a battlefield environment. Knowledge management is extremely important and the reorganization and realignment of functions of information assurance and knowledge management have increased the capabilities of ARL as well as enhanced the contributions to the DoD community in terms of computational applications, and science and engineering applications. High performance computing also uses modeling and simulation tools with various applications and has led to new science in the areas of nantechnology and nanomaterials.

An effort was also made during this period to improve internal cohesion within ARL, thus providing opportunities to reestablish more efficient and effective team operations. Creating new technology to protect the future warfighter, the directorates focused their efforts on new and innovative ideas. ARL was a leader in battlefield sensors and electronic devices, providing revolutionary capabilities for soldiers to preemptively detect and target the enemy. Scientists also developed novel power sources and sophisticated new RF and electro-optic devices, thus innovating signal processing algorithms that will make the next generation of weapons and platforms smart and survivable. In computation and informa-

Interview with Dr. James Wade, Director, SLAD

Question: What has been SLAD's impact on information warfare and warfare of the future?

WADE: There was basically nobody in the Army that could do any work in that area when SLAD was formed. Now it is one of our biggest activities–understanding what information threats are, i.e., malicious viruses and codes, and evaluating Army systems...and making sure that it is hard to do and that our soldiers understand what to do if they are attacked that way. We work quite a bit with many of the other agencies to try to do that. Now we have 80 or 90 people involved almost exclusively in looking at information threats.

Question: On a broader level, how has SLAD's overall mission impacted the effectiveness of the American military?

WADE: Army systems work better because of us–everything from Abrams, Bradley, Black Hawk, Apache, Patriot. Army systems do a better job functioning on the battlefield and protecting our soldiers than they would have without us, and that is from a ballistic perspective, from a chem/bio perspective, from an information perspective. We are proud of our contribution, and there are a lot of other people that are responsible for it as well.

tion, ARL provided fundamental science needed to enable American warfighters to forecast, plan, rehearse and execute missions before the opposing force completed their basic mission planning cycle. The development of collaborative training, mobile self-organizing networks, advanced simulation, interdisciplinary applications using high-performance computing, and battlefield effects are among the initiatives supporting these advances. Weapon and material research provided science and advanced, lightweight materials technology that made the soldier and the Army's future weapon systems more lethal, survivable, sustainable, and strategically deployable to ensure dominance, while providing individual protection, advanced armors, armament technologies and unmanned ground systems. Human research and engineering efforts assured that soldiers operated effectively on the battlefield and with enhanced survivability in lethal environments through cognitive engineering and basic research in vision, audition, and stress measurement that improved soldier analysis and decisionmaking when receiving vast amounts of data. ARL also lead the modeling and simulation efforts within the Army in the areas of ballistics, nuclear, biological, chemical warfare, and information and electronic survivability/lethality for Army systems. This would help enhance the ability of acquired systems to survive and function against the full spectrum of threats. In vehicle technology components were provided for future systems that are lighter, faster, and stronger to reduce the Army's battlefield fuel consumption.

Basic Research

A fundamental aspect of ARL's contribution to leap-ahead technology is basic research which, while longer term in scope, will often produce paradigm-shifting results. In the development of advanced chemical and biological protective materials, nanomaterials such as dendritic polymers represented a technological breakthrough that provided a means of making emerging chemical/biological concepts and systems more practical and affordable for individual protection, detection, and decontamination. ARL designed, developed and evaluated materials and material systems for application in protective clothing, masks, and detection and decontamination equipment. These enabling technologies were transitioned to the Soldier, Biological and Chemical Command and the Army Medical Research and Development Command for inclusion in developmental programs focused on protecting military personnel from chemical and biological attacks. Major accomplishments in FY 2000 included the development of a next generation reactive topical skin protective cream for chemical agent resistance and decontamination; the development of nanoencapsulated enzymes for soldier clothing; and nanomanipula-

ARO *facilities are strategically located in Research Triangle, NC.*

tion conditioning for enhancing biological agent detection.

Eric A. Cornell, Wolfgang Ketterie and Carl Wieman were Nobel recipients in 2001 for their achievements in physics, partly or wholly supported by ARO. Past ARL-affiliated Nobel recipients include Robert F. Curl, Alan J. Heeger, Alan G. MacDiarmid, and Richard E. Smalley for their achievements in chemistry, and Zhores I. Alferov, Herbert J. Kroemer, Donald M. Lee, and Daniel C. Tsui for similar achievements in physics. ARL was also a major participant in the semiconductor revolution that influenced photonics technology and the effort to direct light with the wind, and the technological effort to produce super critical water oxidation in a detoxification effort to eliminate chemical and biological agents. Revolutionizing the warrior soldier was an objective at MIT, where one major effort was the development and improvement of protective clothing effective against chemical and biological threats, and capable of providing treatment prior to the arrival of medical personnel.

Investments were made in infrared detectors, especially with the first color prototype, and in calibration technology for helicopters with Princeton University. Challenges pertaining to the future Army necessitated innovative ideas and influenced the introduction of biotechnology into engineering and physical sciences arena. Optical technology and the development of an electronic eye and a sensitive nose with the capability of smell were designed to enhance the deployment of robotics under battlefield conditions. Target recognition and land mine detecting were also primary challenges that were influenced by quantum computing.

Applied Research

Information Technology

Information technology for the battlefield continued to

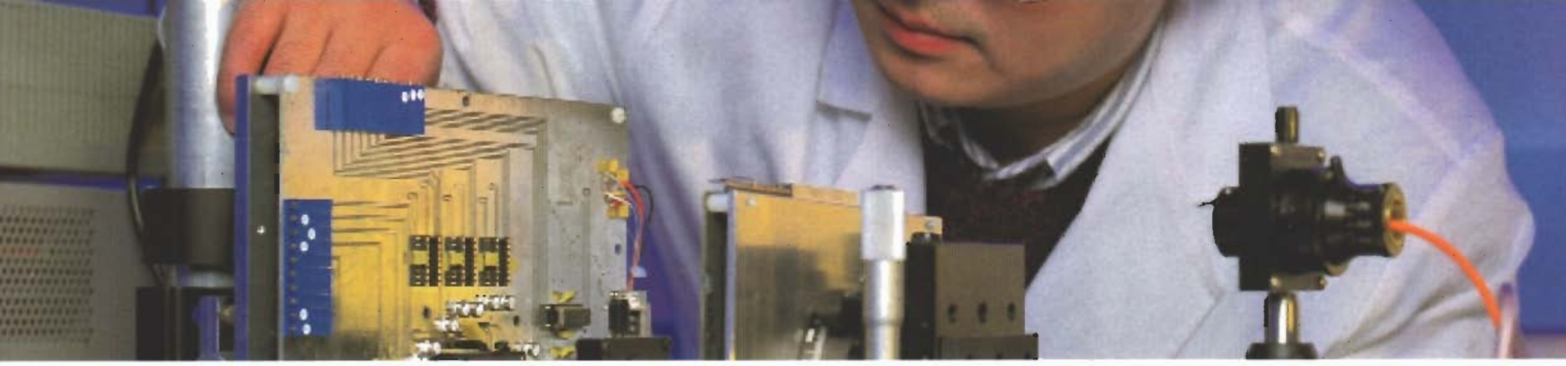
Interview with Dr. Jim Chang, Army Research Office

Question: How has ARO been able to provide new innovations and basic research for so long?

CHANG: There are two reasons. One is the set single investigator program, and the second reason is the valuable and very confident program managers we have at ARO – they are all Ph.Ds. I don't think any other funding organizations in this country can claim that. All program managers are given the opportunity to have 20 percent of the time off to be adjunct professors at the universities to conduct the research, to direct postdocs and Ph.D. students.

Question: How did the trimming of the defense budget affect what ARO does?

CHANG: The bottom line is that providing continuous innovation for the Army cannot be continued with the shrinking dollar. It's huge if you think about it, from $110 million to $50 million. Fortunately, because of smart people, we have been able to deal with the dwindling single investigator dollar problem. They are extremely respected by the national and international academic/scientific communities. On top of that, they're well-respected by peers in the government and other funding agencies.



drive ARL's contribution to the Army Beyond 2010. There were many important breakthroughs in this period. ARL helped develop a dual-band forward-looking infrared (FLIR) camera, which enabled operation in a wider range of ambient conditions, including day, night, fog, and smoke. The imagery from the wave bands easily fused into a single composite color image that provided the observer more information about a scene than could be previously obtained. This enhanced capability to view the battlefield greatly increases the system's ability to select targets out of clutter and to distinguish targets from decoys and defeat other enemy countermeasures. Battlefield information issues were also addressed by the Warrior Extended Battlefield Sensors Program, through which ARL developed energy-efficient networks and acoustics propagation studies for battlefield sensors that enable more effective communicate among soldiers and their commanders. The technology was envisioned to revolutionize surveillance and reconnaissance operations on the battlefield. Finally, work continues on the Integration Meteorological System (IMETS), with the goal of forecasting down to a one-kilometer area. It will also be useful in case of chemical or biological attacks on American soil. A similar technology, the Integrated Weather Effects Decision Aid, was also developed to assist the battlefield commander to deploy helicopters, tanks or aircraft, along with the type of weapons systems, based on the expected weather conditions. In addition, sensors used during the operation will provide audio sounds that would disorient aggressor forces.

A fundamental aspect of obtaining battlefield information lies in trying to extract it from potentially dangerous areas. ARL was successful in robotic and autonomous platform technologies and played a pivotal role in the development and demonstration of technologies that enabled the employment of unmanned ground vehicles in military applications. The Demo III Program aimed at developing technologies for integration of vehicle platforms and conducting field experiments using Army and Marine Corps personnel. The primary goal was to develop autonomous-mobility technology to enable an experimental unmanned vehicle (XUV) to tactically maneuver over rugged terrain as an integral part of a mixed force of manned and unmanned vehicles. Implicit in this goal were the requirements for the unmanned ground vehicle (UGV) to maneuver at speeds that were comparable to manned vehicles and function reliably without requiring additional specialized personnel. A new model of Demo III XUV was used in constructive and virtual simulations at the Mounted Battle Laboratory. A three-dimensional dynamic simulation of the base-case XUV was completed which proved critical for the mobility and sensor stabilization system design for the Demo III vehicles. Demo III demonstrated the capability to perform multiple functions in tactical operations.

Weapons/Lethality

Ensuring combat overmatch for the FCS (Future Combat System) and the Objective Force continued to be a significant challenge. ARL met this challenge through focused efforts in insensitive, high-energy propellants and munitions which offered increased lethality in more compact weapon systems while reducing vulnerability to attack; kinetic-energy penetrator concepts that enhanced or maintained lethality in more compact configurations; and multifunctional warhead concepts that can defeat a full spectrum of targets (armor, bunker, rotocraft, and troops). ARL was the leader in the investigation of terminal effects of direct-fire armaments systems, and the application of that knowledge to develop lethal mechanisms for penetrators and warheads delivered by large-caliber gun systems or small and medium missiles systems to defeat all classes of armors. Technologies developed were critical to weapon system developments at the Army Armament RDE Center and the Aviation and Missile RDE Center that included the Compact Kinetic-Energy Missile (CKEM), the Tank Extended-Range Munition (TERM), the Line-of-Sight Anti-Tank Missile that provided lethal, accurate anti-tank fire using kinetic energy missile technology (LOSAT), and the Advanced Kinetic-Energy Penetrator. ARL also continued to investigate electromagnetic (EM) and electrothermal chemical (ETC) gun technologies because of their potential leap-ahead capabilities to defeat future threats, including platforms equipped with reactive armor and active protection systems. These guns can be integrated with electric vehicle propulsion and armor systems to provide an efficient, highly mobile, and deployable ground maneuver force.

ARL continued to develop technologies to provide overwhelming lethal force, and the highest levels of survivability to the U. S. soldier. Technical and scientific accomplishments include enhanced lethality and survivability of the Abrams Tank, assured through research and development in armor mechanics and advanced penetrator-defeat technologies, and also by providing designs for reducing vulnerability in the

Interview with Ms. Jill Smith, Director, WMRD

Question: How have the goals of Army transformation affected what WMRD does?

SMITH: Back in '97, they hung a banner in the directorate that said, "the challenge is to make our heavy forces lighter and more deployable and our light forces more lethal and survivable." That was before the transformation. We are transitioning technology for the original field and future combat systems, so I think that says that we were on the right path.

Question: What are some of the biggest challenges WMRD has faced?

SMITH: I think that probably the biggest challenge is trying to get very top-notch scientists, engineers, and support staff. You can't get a college degree in ballistics. To actually learn the science of weapons and how you change the terminal penetration on things – well, those kinds of things take a lot of internship or on the job training from experts. In-house research and development is absolutely critical to having the best technology in the world, and you can't have it all done in private industry. Our government scientists and engineers are absolutely critical in having the best technology in the world.

ammunition compartments. In the area of lethality, ARL worked with the RDECs to provide integral technologies for the M829 family of Abrams kinetic-energy ammunition, the fielded M829A1 and M829A2 and the developmental M829E3. Contributions also included the lethal mechanism design (i.e., the sub-projectile), high-performance propellant technology, launch and flight ballistics, and lightweight composite sabot design. Finally, ARL developed a non-lethal munition fired from the M203 grenade launcher and a crack-resistant face shield for riot helmets, both of which were fielded to troops in the Balkans and Somalia employed in peacekeeping engagements.

Soldier Performance/Battlefield Coordination

A cornerstone of the FCS and the Objective Force is ensuring that soldiers will function with maximum effectiveness under all conditions on the higher-technology battlefield. ARL conducted research to define and quantify soldier capabilities and limitations and apply this understanding to the design and development of soldier-system interfaces. Scientists and engineers worked closely with soldiers to identify and develop solutions to current and future performance problems. Basic research in auditory and visual perception, and applied research in cognitive engineering and logistics provide the understanding required by material developers to build systems that greatly enhance soldier performance. In addition to the research function, ARL championed the soldier in the material acquisition process by providing leadership in human factors engineering and the application of MANPRINT to Army acquisition. ARL's support to combat developers, PEOs, PMs, and the Army's test and evaluation effort is critical to systems success, and ARL's contributions have significantly improved system performance and reduced life-cycle cost.

As the twenty-first century approached, the Army needed a command and control vehicle (C2V) that would permit staff to accomplish command and control operations while moving. ARL was asked to develop modeling techniques similar to those on the Comanche helicopter and the Fox vehicle, but with the capability of deploying more personnel. Cognizant of the requirements for effective communication and the need for the command staff to be close enough to the leading edges of the formation, the critical initiative that evolved is to have a C2V suitable to support the FCS. To some extent, the problems pertaining to command and control during the peacekeeping deployment in Bosnia influenced the requirement for the C2V. It has led to further measuring of team behaviors or performance, especially the development of command and control tools. Another interesting aspect is the measurement of command and control involving multinational teams.

HRED efforts were also oriented toward soldier-system performance impact on force effectiveness. MANPRINT stresses the integration of manpower, personnel, training, human engineering, system safety, health hazards, and soldier survivability. Major successes in the use of MANPRINT were achieved in the development of the Fox Nuclear, Biological and Chemical (NBC) Reconnaissance System that was accomplished by the Integration Methods Branch use of IMPRINT and Human Figure Modeling. Success was also attained in the Joint USMC-Army Acquisition Program of the XM777, Lightweight, Towed Howitzer, for which the Air Warrior Team received the MANPRINT Practitioner of the Year Award for improvements of the process which produced the first aviator human figure computer program. Another achievement was the development of the Objective Individual Combat Weapon (OICW). The lighter weight, smaller footprint, and lower profile of the XM777 improves strategic deployment, tactical mobility, and survivability, and will replace the M198 howitzer as a direct and general support system for Army light and interim forces. The OICW provides the infantry soldier with a decisive overmatch capability while increasing versatility and survivability by increasing the standoff range to exceed 1000 meters, providing day/night operational capabilities, and providing significant improvements in lethality and target effects. ARL recognizes that new technologies for the future battlefield will be characterized by the rapid introduction of cognitively demanding weapon and information systems. Successful command and control of the Objective Force will place high cognitive demands on leaders and soldiers. Objective Force decision-making will occur under conditions involving intense time pressure, information overload, fatigue and geographical dispersion.

Survivability and Lethality Analysis Efforts

ARL is responsible for the vulnerability and lethality analyses of all developmental and fielded weapon systems and soldiers. A vital aspect of the survivability, lethality, and vulnerability (SLV) mission was the vulnerability assessment of the

Major Shared Resource Center

ARL manages the Major Shared Resource Center (MSRC) at APG, MD. Created under the High Performance Computing Modernization Program (HPCMP), it is one of the largest high-performance computing facilities in the world, providing the DoD research and development community increased computation and networking capabilities including battlefield simulation, modeling of advanced weapon systems, cross-discipline applications and weapon system design and development. ARL's researchers are leading the way in the emerging computational fields of data mining, knowledge management, scientific visualization, and information management.

The High Performance Computing Modernization Program (HPCMP) was initiated in 1992 in response to congressional direction to modernize the Department of Defense (DoD) laboratories' high performance computing (HPC) capabilities. The HPCMP was assembled out of a collection of small high performance computing departments each with a rich history of supercomputing experience that had independently evolved within the Army, Air Force, and Navy laboratories and test centers.

The HPCMP provides the supercomputer services, high-speed network communications, and computational science expertise that enables the Defense laboratories and test centers to conduct a wide range of focused research, development, and test activities. This partnership puts advanced technology in the hands of U.S. forces more quickly, less expensively, and with greater certainty of success. Today's weapons programs, such as the Joint Strike Fighter, Comanche Helicopter, Medium Tactical Vehicle Replacement, and the Javelin Missile program, have benefited through innovative materials, advanced design concepts, improved and faster modification programs, higher fidelity simulations, and more efficient tests.

Recent Technology:

Laser Radar (Ladar)

Soldiers have an increasing need for technology that can detect and identify obscured targets. In support of DARPA's Counter Camouflage, Concealment and Deception Program, ARL conducted a foliage penetration field experiment to determine the viability of using a three-dimensional ladar to detect and identify targets under trees. Using a ladar system developed in-house, ARL collected data against several military targets concealed in foliage at Aberdeen Proving Ground. With the ladar mounted atop a mobile boom-lift—to simulate deployment on a UAV or other air vehicle—data was collected from multiple positions above the treetops. The resulting multi-aspect 3-D ladar data were then merged to form a composite 3-D image that could be manipulated by computer to reveal the concealed targets.

The success of the field experiment supported the formulation of the DARPA Jigsaw program. Jigsaw's goal is to develop ladar as a primary combat identification sensor for Future Combat System platforms. By combining multi-aspect 3-D data to permit visualization from alternate viewpoints, the Jigsaw ladar systems will enable humans to identify targets with high confidence under a wide range of stressing environments (e.g., targets fully or partially hidden by foliage, camouflage, etc.), without the aid of automated target recognition.

Over the past several years, ARL has been developing its unique ladar technology to allow the system to be small, low-cost, and producible using commercial-off-the-shelf parts. Additional data collections have been performed against targets in other environments (e.g., under camouflage, in tall grass) from both air and ground level perspectives. Other applications for ladar technology include robotic visualization, urban scenarios, smart munitions, and unattended ground sensor platforms.

development of a Theatre High-Altitude Area Defense (THAAD) system. The comprehensive analysis involved an evaluation of the effects of all major electromagnetic elements, including EM interference, EM radiation operations, EM radiation hazards, EM pulse, electrostatic discharge, and lightning effects on critical functions and critical subsystems/components of the THAAD system. The analysis provided THAAD program mangers and Army decisionmakers with early feedback on SLV designs options that had near-term and mid-term impacts, as well as anticipated far-term SLV improvements that addressed reactive threats, thus providing early insight into Planned Improvement Program options. On June 23, 2000, THAAD received program Milestone II approval and on September 27, 2001 the U.S. governmental and industry team developing THAAD achieved a major milestone by successfully completing the critical design review for the radar segment. The THAAD Project Office was placed under the operational control of the Ballistic Missile Defense Organization on October 1, 2001 for the development and conduct of extensive ground tests. ARL developed realistic trajectory models for targets and missile using available THAAD field data and threat trajectory data in addition to developing multiple target trajectories for use with IR scene generation of infrared countermeasures (IRCMs).

Another analysis project involved the Comanche, the Army's next generation helicopter, designed to perform armed reconnaissance and attack missions. It will significantly expand the Army's capability to conduct reconnaissance, security, and attack operations in all battlefield environments, day or night, and during adverse weather using its advanced electro-optical sensors, aided-target recognition, and sensor-weapons integrations. The Comanche's digital communications capacity will enhance the Army's capability to win the battlefield information war, and allow interface with the Joint Surveillance and Target Attack Radar System (JSTARS) and other joint sensors and weapon platforms. A commitment was received in FY98 from the Comanche helicopter Project

Manager Office to support the continuation of the analysis of the potential airborne chemical threat that the RAH-66 helicopter may experience on the modern battlefield. A chemical/biological agent dispersion computer model was used to develop a baseline-modeling scenario in coordination with the Comanche helicopter developer, Boeing/Sikorsky.

Organizational Initiatives

At this time, ARL consisted of laboratories and its headquarters in Adelphi and with major sites at Aberdeen, Maryland, the Research Triangle Park in North Carolina and White Sands Missile Range in New Mexico, in addition to research elements co-located with the National Aeronautics and Space Administration (NASA) in Cleveland, Ohio and Langley, Virginia and a worldwide presence through various research and business partnerships that included the United Kingdom, Japan and Germany. At Adelphi, the completion of the Zahl Physical Sciences Laboratory was the last of the construction authorized under BRAC. The facility houses the staff of SEDD and the ALC component of the CISD. The Zahl building also includes the Advanced Material Growth and Processing Facility, Display Materials Research Facility, and the Advanced Microanalysis Facility. Movement into the facility began in August 1999 from ALC locations. SEDD personnel who moved from Fort Monmouth, NJ and Fort Belvoir, VA to a temporarily leased Shady Grove laboratory facility, were the first scientists and engineers to relocate into the Zahl Physical Laboratory. The Shady Grove facility was completely vacated in February 2000.

The future mission of ARL is not only influenced by Army directives. During the early years of Whalin's tenure, ARL recognized that despite the reputation of the scientists and engineers on staff, it still faced challenges regarding personnel, as the retirement process threatened to reduce both the scientific and organizational knowledge base. This will occur as the need for skilled, specialized scientists continues to increase. To this end, ARL initiated or revitalized several personnel programs designed to ensure its position as a top recruiter of scientific talent. Perhaps the most significant of these was the Science and Technology Academic Recognition System (STARS), which recruited minority scientists and engineers to ARL. The dual fellowship/recruitment initiative assisted top students from ARL's partner schools in Historically Black Colleges and Universities and Minority Institutions. All of these programs clearly recognize that the U.S. military must stay ahead of the world not only in military technology, but also in the quality of scientists developing that technology.

Section 4 - September 11th and After: The Future of ARL

1945-1990 *1991* *1993-1998* *1998-2001* ***2001 & beyond***

At 8:45a.m. on 11 September 2001, terrorists crashed American Airlines Flight 11 into the World Trade Center's North Tower. While Americans scrambled to make sense of what had happened in downtown Manhattan, a second plane, Flight 175 of United Airlines, crashed into the South Tower only 18 minutes later. The horror in New York was compounded at 9:43 a.m. when American Airlines Flight 77 slammed into the Pentagon. In 58 short minutes, the United States had been significantly attacked on its own soil for the first time since Pearl Harbor in December of 1941. Americans knew the country was at war.

ARL's response to these events was twofold. First, the Emergency Operations Center (EOC) was up and running at 10:30a.m. that day, less than an hour after the attack on the Pentagon. The EOC has several roles: maintaining secure communications, coordinating all Enduring Freedom/Noble Eagle support, and maintaining records and documentation of all its efforts. In addition, the EOC has worked on a number of major projects since its inception. One was the development of emergency procedures to cover a spectrum of possible threat contingencies. Personnel assigned to the EOC have been working closely with representatives from every staff element to develop these procedures. Almost all either have been tested through various real-world events or war-gamed for validation. The EOC is refining all of its procedures. Another project involved the successful development of reliable communications architecture for both unclassified and classified e-mail. Consequently, ARL now has virtually instantaneous access to the various DoD resources. A third major project was the identification and justification of force protection augmentation. The project resulted in the approval of thirty activated National Guard soldiers and four Individual Mobilization Augmentees (IMAs) to support ARL at Adelphi.

While ensuring the security of the American homeland was the first priority immediately following the attacks, it became clear that the U.S. military would have to mobilize offensive efforts in order to undermine Al Qaeda's base of operations in southwest Asia. As DoD and various other federal agencies fortified America's

Question and Answer session with Dr. Robert Whalin, Director, ARL, 1998-2002

Question: How has the war on terrorism impacted ARL?

WHALIN: Well, it's going to impact everybody in the country. But we are much more conscious about the international security front, about all types of operational security. It doesn't mean that we need to close down our research – especially our basic research – because research advances are international. As much as we might like to think so, we don't have the corner on all the smart people in the world, and indeed research thrives in an open and competitive environment.

Question: Has ARL's mission been affected?

WHALIN: Our Army vision and Army doctrine had already talked about all of the various new missions of the Army, the much more intense pace of operations, and all the different kinds of operations we are involved in – peacekeeping operations, our current war on terrorism, (which is in a sense, more the same in that it focuses on small operations as opposed to a major theater of war) . More agile operations could mean peacekeeping or special forces operations. You would think that might have been written post 9/11 rather than pre-9/11. So I think our new Army vision of the past three years, which focuses on agility, on deployability, on lethality, communications, was absolutely amazingly on target.

WHALIN: We have come a long way in the last decade toward achieving a much more integrated and seamless integration of the talents of each of the major segments of our research establishment, and , in fact, I believe that this is a very critical thing indeed for the United States' position as a world economic power.

The ARL team's current interpretation of this mission is...

Provide innovative science, technology, a

defenses, a measured and expeditious review of the evidence from September 11th was underway. Then, on Sunday, 7 October, Americans turned on their television sets, expecting to watch their favorite football teams. Instead, they were greeted with a preemption by the broadcast networks, and an announcement from President Bush: "On my orders, the United States military has begun strikes against Al Qaeda terrorist training camps and military installations of the Taliban regime in Afghanistan. These carefully targeted actions are designed to disrupt the use of Afghanistan as a terrorist base of operations and to attack the military capability of the Taliban regime." The war that had been brought home to American soil would now be fought abroad and would involve a massive mobilization by American armed forces.

In his speech, the President focused on the American armed forces, and the sacrifice asked of them in the ongoing conflict. Addressing them, he indicated: "to all the men and women in our military — every sailor, every soldier, every airman, every Coast Guardsman, every Marine — I say this: Your mission is defined. The objectives are clear. Your goal is just. You have my full confidence, and you will have every tool you need to carry out your duty." Much of the technology intended for Army Transformation would now be deployed to assist American soldiers in carrying out their duties.

While ARL's immediate contributions were important in facilitating coordination among DoD agencies and securing the research being done at ARL facilities, its most important mission in the coming years will be to continue to provide the tools the President mentioned in his 7 October speech. As the past ten years have shown, this technology is essential, both in the war on terror and the defense of American interests at home and throughout the world. The new campaign marks a transition in American military priorities, as the primarily peacekeeping emphasis of the 1990s makes room for the additional need for the United States to wage an offensive war. Technologies meant to protect American soldiers were now accompanied by technologies developed to identify enemies and to help coordinate the United States' global responses and initiatives in the war against terrorism.

Since the terrorist attacks, U.S. armed forces have engaged in two major operations – Operation Enduring Freedom in Afghanistan (OEF) and Operation Iraqi Freedom (OIF). ARL participated in the development of several technologies that were fielded in these operations to assist soldiers in carrying out mission objectives. In Afghanistan, the acoustic battlefield aid, which uses acoustic sound to identify areas where U.S. military assets can and cannot be detected, was deployed to the 25th Marine Expeditionary Force. The search for top Taliban and Al Qaeda leaders was further assisted by the use of PacBots, which were developed in coordination with DARPA and manufactured by iRobot. These small robots were deployed to Afghanistan to clear caves and buildings, marking the first time that the U.S. military used robots as a combat tool. The robots were integrated with ARL-developed sensors prior to deployment. Finally, the deployment of the already heralded FALCons to soldiers enabled them to translate scores of documents left behind by the Taliban regime.

While OEF utilized these technologies so as to end Al Qaeda operations in Afghanistan and stabilize the new regime, Operation Iraqi Freedom would see a more extensive use of ARL-developed technology in combat operations. While an exhaustive list of these technologies is unavailable due to the ongoing conflict, among technologies fielded were the Integrated Meteorological System (IMETS), which provided operational weather forecasts and predicted weather patterns in the battlefield. ARL has worked on technology enhancements to address specific areas identified by soldiers such as forecasting high wind events and dust dispersion – critical weather factors in the Iraqi desert. The system was deployed to the 3rd Infantry Division, the 173rd Airborne Brigade, the 101st Airborne Division, and Coalition Land Forces Component Command. Further, the PILAR/Acoustic

Interview with Dr. Robin Keesee, Director, HRED

Question: How have recent historical developments affected what you do at HRED?

KEESEE: The major impact has been on the increased peacekeeping that the Army has been called to do through the 90's. Bosnia has been more of an influence than 9/11, although the 9/11 impact will be seen in the coming years. There is more investment in the human behavior and intelligence-gathering process.

Question: Looking to the future, with the emphasis on the individual soldier, how do you imagine technology changing?

KEESEE: Over the last two years, there is more awareness of task workload issues with dismounted soldiers. There had been a presumption that if it worked on a desktop or in a crew station, then it should work on a dismounted soldier. Conceptually, to some extent, that's true, except for the interaction between physical work and cognitive capacity, and as we carry a backpack or just physically go through a race, we don't have the cognitive perspective we had before the race or before the 20-mile trek. And that really affects how well we're going to be able to use information technology. There is also a new appreciation for team processes, team sharing of information in infantry squads.

Interview with Dr. James Gantt and Dr. N. Radhakrishnan (Radha), CISD

Question: What is the significance of your directorate to contemporary technological development?

RADHA: The importance of information technology-oriented research is pretty evident now. Anything you touch now is computers, and things like information fusion, data fusion, are getting to be more involved in problems within the battlefield.

Question: What is one example of a specific development in your field in the past ten years?

GANTT: The area of information assurance, an area that didn't exist 10 years ago in most people's minds. But it became an important commodity because more and more in the Army, we are making decisions based on the information that is provided to us.

RADHA: The other thing that we have done here in the past ten years is the contributions we have made to the Army and the DoD community in terms of computational applications – science and engineering applications based on computational science. We believe strongly that by using simulation tools, using high performance computing, we can reduce the time frame from research to acquisition through computer simulation.

Gunfire Sniper Detection System was fielded to the U.S Special Operations Command. Developed in conjunction with Program Manager, Close Combat Systems, ARDEC, the system, which includes both ground-based and vehicle-mounted variants, uses the sound of a small arms weapon or bullet in flight to provide the relative azimuth, elevation and range of the origin of the shot – a technology which will prove increasingly important in the U.S. Army's stabilization and peacekeeping missions in Baghdad and other Iraqi urban areas. Finally, ARL helped develop the M152 Remote Activation Munition System (RAMS), which functions as a remote detonator for explosives and the operation of electronic items. It has also been fielded to the U.S. Special Operations Command, which praised the system as a "vital advance in technology for the Special Operations Forces in their missions ranging from humanitarian assistance to counter-insurgency to low intensity conflict to full scale war."

ARL is committed to providing the technological underpinnings to systems being developed, improved, or recapitalized by its customers—principally the Army's research, development and engineering centers. Its mission will continue to be to "execute fundamental and applied research to provide the Army with the key technologies and the analytical support to assure supremacy across the spectrum of military operations." The ARL team's current interpretation of this mission is "Provide innovative science, technology, and analyses to enable Army Transformation." Its more than 2,000 employees (of which 1,250 are engineers and scientists) will continue their diligent efforts in support of the defense of both America and its soldiers. Further, as the Army leader in implementing innovative cooperative agreements (such as the Federated Laboratory and its follow-on, the Cooperative Technologies Alliances), ARL will continue to facilitate the combination of talents and resources of government, industry and academia to perform advanced research in communications, displays, sensors, robotics, and power and energy. The Laboratory has a large number of agreements with research

ARL's Major Shared Resource Center is one of the world's top 10 most powerful computing sites.

universities, including one with the Massachusetts Institute of Technology for the Institute for Soldier Nanotechnologies. ARL and the Army Natick Soldier Center will work with MIT to equip future soldiers in uniforms and gear that can heal them, shield them and protect them against chemical and biological warfare.

Among some of the many technologies ARL will provide in the coming years are the following:

Lightweight Vehicle Armor Technology

ARL is engaged in a joint effort with the Tank-Automotive RDE Center to develop ballistic protection technologies for medium and lightweight future ground vehicles. The primary goal is to develop armor technologies necessary to field survivable Future Combat Systems for the Objective Force. ARL is integrating advanced materials, structures, and armor concepts to provide lightweight protection against future medium-caliber cannon threats, residual debris from defeat by active protection systems of large-caliber kinetic-energy penetrators, light and medium shaped-charge warheads, top-attack munitions, and anti-vehicle mines.

Improved Individual Ballistic Protection.

ARL is developing ballistic protection technologies critical to individual soldier protection. These technologies will be transitioned into Natick Soldier Center developmental systems. These efforts are leading to development of prototype protection configurations consistent with Natick Soldier Center technology insertion requirements for personnel armor systems that can defeat emerging ballistic threats at significantly reduced weights. Personnel threats this program is aimed at defeating include conventional fragmenting munitions and bullets, emerging low-mass/high-density fragmenting munitions, and emerging armor-piercing tungsten-core rounds.

Novel Lethal Mechanisms for Gun and Missile Systems

ARL is the Army's leader in the investigation of terminal effects of direct-fire armament systems and the application of that knowledge to develop lethal mechanisms for penetrators and warheads delivered by large-caliber gun systems or small and medium missile systems to defeat all classes of armors. ARL's anti-armor research program is directed toward increasing the lethality of kinetic-energy penetrators, shaped-charge warheads, and explosively formed penetrators without seriously increasing the vulnerability of the weapon system. Technologies developed in this program are critical to weapon system developments at the Army Armament RDE Center and the Aviation and Missile RDE Center — including the Compact Kinetic-Energy Missile (CKEM), Tank Extended-Range Munition (TERM), Line-of-Sight Anti-Tank Missile (LOSAT), and Advanced Kinetic-Energy Penetrator.

In many ways, ARL will best contribute to America's mission abroad. .

by continuing the initiatives it ha

Digitizing the Battlefield

ARL identified four broad research areas in which the Army must excel if it is to fully exploit the information technology revolution and close the opportunity gap.

Sensing technologies that will enable the war fighter to have automated, near perfect information of the battlefield in all environments. Automation of sensors is the key to the digitized battlefield.

Distribution technologies that ensure the right information gets to the right place at the right time, regardless battlefield environment.

Analysis technologies that significantly reduce the force structure required to process, in real time, the vast quality of information required to provide the commander "first hand knowledge" of the fast-paced, widely dispersed operations of the future battlefield.

Assimilation technologies to turn this "first hand knowledge" of the battlefield into actions that will allow our forces to move from today's "quick draw" engagements to a "hunter and the hunted" type of engagement in the future.

Electrothermal-Chemical Gun Technology for Multirole Armaments

ARL is developing Electrothermal-Chemical (ETC) propulsion technology for enabling significant lethality enhancement in current and emerging direct-fire armament systems. ETC is a hybrid gun propulsion concept that utilizes electrical energy to augment and control the release of chemical energy from propellants to achieve significant performance enhancements in existing and emerging large-caliber gun systems. Alternatively, ETC technology permits equivalent lethality in a smaller gun caliber to that of current large-caliber guns. Thus, this technology is not only applicable to medium-caliber armaments for Future Combat Systems, but it is also a key to achieving significantly improved performance of the large-caliber gun of the current Abrams tank fleet or as a technology enabler for emerging medium-weight combat vehicles.

Microturbine Engines

Gas turbine engines power the Army's Apache helicopters and M1A2 Abrams tanks. But someday, a gas turbine engine – a microturbine—might replace the batteries to power your portable radio or CD player. In the future, the individual soldier's equipment, as well as commercially available items, might be powered by a microturbine. This technology represents an innovative approach to providing a power source that potentially has some five to 10 times the energy density of batteries.

Fuel cells

Simple devices capable of directly converting the chemical energy of a fuel into electrical power and water – offer several advantages over batteries as potential power sources. They are more efficient than combustion technology and, since a fuel cell generates electricity without combustion, it does not produce air pollutants. Fuel cells are expected to be an important component providing electrical power to the Army – large scale for vehicle mobility and small scale for the individual soldier. However, the development of improved hydrogen *focused on in the past ten years.*

sources for hydrogen-air fuel cells and the development of membrane electrolytes and electrocatalysts for direct methanol fuel cells remain a challenge. ARL is developing more efficient catalysts, membrane electrolytes and reforming logistic fuels to provide the hydrogen source for hydrogen fuel cells. ARL's Small Business Innovation Research Program has produced several prototype direct methanol fuel cell systems.

Robotics

ARL is executing DoD's Ground Vehicle DEMO III program. Robots are expected to serve as force multipliers on the future battlefield by augmenting human forces in high-risk missions. They will also expand a unit's capabilities by increasing situational awareness, providing remote fires on demand and reducing the logistics burden by shrinking the size of combat vehicles. A major thrust of the program is to integrate new technologies on the testbed vehicles. Interaction between the robots and the soldiers is a major requirement so soldiers will be able to supervise operation of the robots rather than directly control them.

Cognitive Engineering

Scientists at ARL are researching various aspects of human performance on the battlefield to optimize the soldier-machine interaction, so that technology can maximize the soldier's effectiveness. Soldiers increasingly are being overloaded with information on the battlefield, but they still have to do a basic job, namely locate and destroy the enemy. Cognitive load is an important issue that must be weighed because if too much information is provided, the soldier could lose the focus of his main objective.

Recent Technology:

ARL partners with MIT in Institute for Soldier Nanotechnologies

ARL and the Army Natick Soldier Center will work with MIT to equip future soldiers with uniforms and gear that can heal them, shield them and protect them against chemical and biological warfare.

MIT won the Army competition for the five-year, $50 million proposal for an Institute for Soldier Nanotechnologies (ISN). Industry will also contribute an additional $40 million in funds and equipment. Raytheon, DuPont and Massachusetts General/Brigham and Women's Hospital are Founding Industry Partners with the institute.

The ISN will focus on six key capabilities. They are threat detection, threat neutralization, concealment, enhanced human performance, real-time automated medical treatment, and reduced logistical footprints (reducing the weight load for a fully-equipped soldier).

To address these, there will be research teams addressing seven technology areas. They are energy absorbing materials, mechanical active materials for devices and exoskeltons, detecton and signature management, biomaterials and nanodevices for soldier medical technology, process systems for manufacture and processing of materials, modeling and simulation, and systems integration.

In addition to military use, great potential is anticipated for civilian use in areas such as medical treatment and police and emergency worker protection.

Appendix I: ARL Organization

The U.S. Army Research Laboratory (ARL) is the Army's corporate laboratory. Its mission is to provide innovative science, technology and analyses to facilitate the execution of full-spectrum operations, enabling Army Transformation and assuring America's supremacy in future land warfare. ARL provides the technological underpinnings to systems being developed, improved or recapitalized by its customers—principally the Army's Research, Development, and Engineering Centers (RDECs). ARL constitutes the largest source of science and technology research and development in the Army. Its more than 2,000 employees, of whom more than 1,250 are engineers and scientists, perform at world-class facilities. Headquartered in Adelphi, MD, ARL occupies major sites at Aberdeen Proving Ground (APG), MD; Research Triangle Park (RTP), NC; and White Sands Missile Range (WSMR), NM. ARL also operates research elements co-located with the National Aeronautics and Space Administration (NASA) in Cleveland, OH, and Langley, VA. ARL is organized into six directorates and the Office of the Director, the Director's Staff, the Office of the Chief of Staff and the Army Research Office.

The Computational and Information Sciences Directorate (CISD) plays a key role in information sciences and technology research within the Army and the Department of Defense (DoD). CISD promotes the use of high performance computing technologies across ARL Directorates, AMC RDECs, and the Defense test and evaluation community; critically reviews the current Major Shared Resource Center (MSRC) hardware and software architecture and develops a strategic plan for the MSRC future; and upgrades ARL's technological infrastructure. CISD also supports the Director's "One ARL" concept by providing the policies, plans and execution for modernizing the laboratory's next generation information technology (IT) infrastructure.

With a research mission focused on battlefield communications and networks, data fusion and knowledge management, battlespace weather and environmental effects, and computational science and engineering, CISD provides the Army with the necessary advances in IT to transition to the Objective Force. CISD operates the ARL DoD MSRC, the Army High Performance Computing Research Center (AHPCRC) and

the ARL Collaborative Technology Alliance in Communications and Networks.

The Office of the Chief of Staff (CoS) consists of subordinate offices, each with specific missions. The Commander leads the corporate level coordinating staff and select elements of the Special Staff to maintain the full spectrum of ARL's business operations. These elements include the Chief Counsel Office and the Public Affairs Office. The Commander also develops productive staff relations with higher headquarters and ensures that taskings and suspenses are completed on time. In addition, the Commander directly oversees the Adelphi Laboratory Center (ALC), including Blossom Point, providing operational and logistical support.

The Survivability and Lethality Analysis Directorate (SLAD) focuses on materiel acquisition programs, including soldier survivability assessments and support for the Army's survivability, lethality and vulnerability (SLV) analysis program requirements. Both DoD and the Army recognize that the survivability and lethality of our systems and soldiers are critical to the success of the Army and the Army Transformation, and SLAD is the only source within the Army that meets the DoD regulatory requirement for a fully integrated analysis of survivability and lethality across all threats.

The directorate performs information operations, vulnerability assessments, electronic warfare investigations and survivability analyses, thereby reducing the overall cost by identifying vulnerabilities and solutions early in the design phase. Research generated by SLAD provides support assessments for major military milestone decisions. SLAD also investigates new technologies, which could radically change the way combat simulations and war games use key data to evaluate the survivability of the Objective Force. It provides the ultra-realistic portrayal of damage within Army simulations to support training, mission rehearsal and development of battlefield tactics.

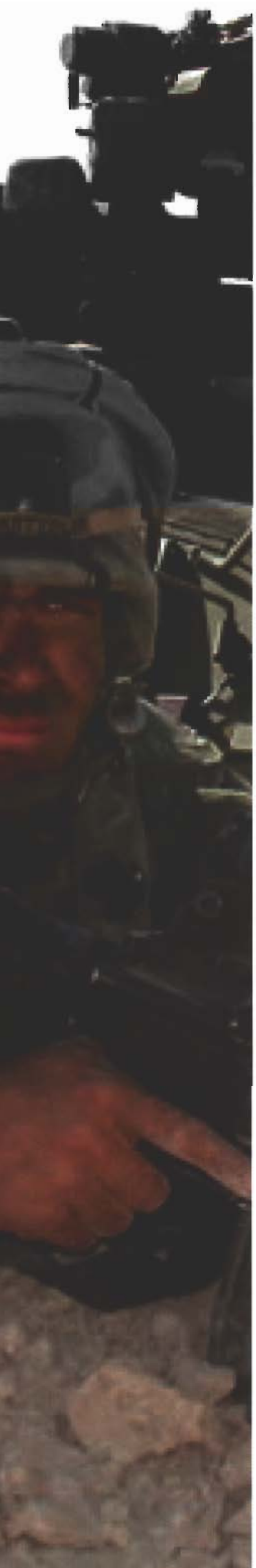
Scientists and engineers working for SLAD rely on modeling and simulation supported by laboratory and field experiments. Tests and model predictions are also performed in support of congressionally- mandated ballistic live fire testing. SLAD's contribution is essential to the successful implementation of the Army Transformation Campaign Plan. Its efforts will lead to the survivability of systems, such as the Future Combat Systems (FCS). SLAD also conducts objective and integrated survivability and lethality analyses (SLA) on systems of the Interim and Objective Forces of Army Transformation and other major and designated non-major Army systems. The analyses quantify the effects of electronic warfare, information warfare, ballistic battlefield threats and meteorological conditions on Army

individual soldiers and systems.

The Weapons and Materials Research Directorate (WMRD) strives to understand the fundamental aspects of chemistry and microstructure that influence the performance and failure mechanisms of advanced materials such as ceramics, advanced polymer composites, advanced metals and multifunctional materials. Coupling theoretical and experimental studies with advanced high performance computing and state-of-the-art experimental facilities, WMRD focuses applied research on future combat vehicle protection, integrated personnel protection, unmanned ground vehicle (robotic) technologies, advanced lethality concepts, smart weapons and munitions, weapons for the light forces and advanced materials for armor and armaments.

The formation of WMRD from the former Ballistics Research Laboratory and the Materials Technology Laboratory combines the Army's ballistics and materials resources at APG. To assure dominance on the future battlefield, WMRD provides the science and technology that make the individual soldier and the Army's future weapons systems more lethal, survivable, and strategically deployable. More than 325 scientists, engineers, and technicians focus research efforts on the Army's unique and emerging needs for advanced armor and armaments technologies. In partnership with the Army Research, Development and Engineering Centers, industry, national labs, academia, and appropriate foreign institutions, WMRD provides the Objective Force and Army Transformation with enabling technologies that will revolutionize the lethality and survivability of America's ground forces. The directorate is currently organized into three divisions that address weapons materials research and technology, ballistics and weapons concepts, and terminal effects phenomenology.

One of today's most difficult challenges is to ensure that the Army's Future Combat Systems will have the same survivability that is provided in the seventy-ton Abrams main battle tank. In pursuit of this goal, WMRD executed an aggressive research program to provide technologies for active protection against large caliber kinetic energy penetrators. WMRD offers responsive solutions and enabling technologies for a more lethal and survivable land force comprised of Future Combat Systems and manned by the Objective Force Warrior. However, WMRD efforts also support ongoing peacekeeping efforts in Bosnia and Kosovo and the war in Afghanistan conducted with Legacy Force equipment such as the Bradley Fighting Vehicle. Additionally, WMRD supports the near-term development and fielding of state-of-the-art combat systems such as the Comanche helicopter. WMRD also manages the



Robotics Collaborative Technology Alliance.

The Vehicle Technology Directorate (VTD) conducts basic and exploratory research in structural and propulsion technologies. Structural research is performed at the NASA Langley Research Center in Hampton, Va., where Army and NASA scientists and engineers work jointly on programs involving structural mechanics and integrity, air/ground vehicle loads and dynamics, crashworthiness, active noise and vibration control, and non-destructive evaluation methodologies. This research provides the technology needed to extend the life of existing Army vehicles and to design affordable future platforms with greater durability, lighter weight and improved crashworthiness.

Propulsion research is carried out at the NASA Glenn Research Center at Lewis Field in Cleveland, Ohio. At NASA Glenn, the technical areas involve gas turbine engine components, propulsion materials, mechanical components, and propulsion system concepts.

The Army partnership with the NASA research centers began in 1969 and has been an enduring success story ever since. The arrangement has enabled Army scientists and engineers to leverage specialized NASA research facilities and to collaborate on joint programs with highly regarded national and international experts in air and ground vehicle technology. VTD research areas include aerodynamics, flight controls, propulsions, structures, and transmission technologies.

The Sensors and Electron Devices Directorate (SEDD) serves as the principal Army organization for research and development in sensors and electron devices technology, ensuring U.S. military superiority and providing the Army with affordable technology for sensing, communications, threat engagement across the electromagnetic spectrum of the battlefield, and in power and energy to provide the soldier with reliable, affordable and portable power. SEDD also manages the Advanced Sensors and the Power and Energy Collaborative Technology Alliance.

SEDD focuses on research and development initiatives that contribute to technological advancement in solid-state physics, radiation effects, electro-chemistry (including fuel cells technology and power conversion), high frequency electronics, photonics, microelectromechanics, wide-band-gap electronic materials, nanoscience, optoelectronics, biodetection, display phosphors, and fabrication process sciences. Research and development results are applied toward Army requirements that include portable power resources, cooled/uncooled infrared detectors, lasers, optical systems, signal processing, fire control, guidance, fuzing application, network sensors, and microwave and millimeter devices.

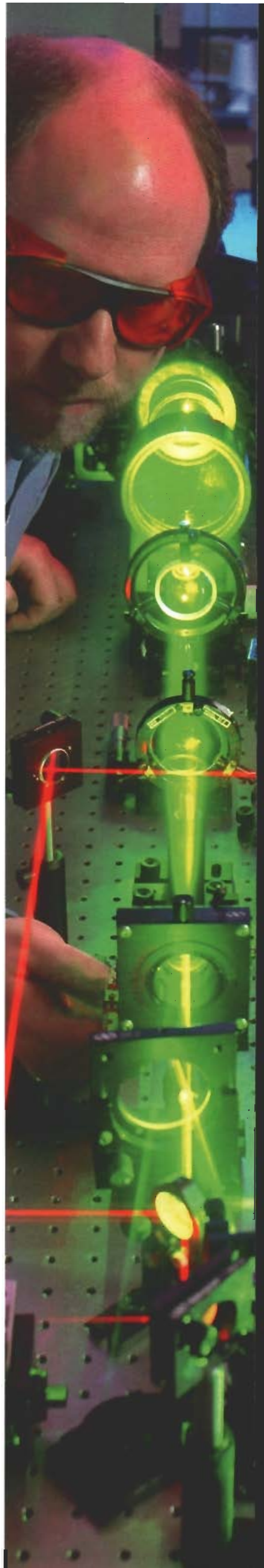
Recent SEDD accomplishments include dual-band and hyperspectral infrared imagery, infrared detectors using self-assembled semiconductor quantum structures, radar cross-section modeling, subwavelength optics, quantum cryptography, automatic/aided target recognition (ATR), scannerless ladar, micro electro-mechanical systems (MEMS) modulating flux concentrator, piezoelectric MEMS for sensors network, a new high energy "air" battery, non-flammable electrolytes for high energy rechargeable batteries, fuel cells for the dismounted soldier, networked sensors, passive millimeter wave imaging technologies, multi-function radio frequency (MFRF) program, and active-protection technology-kinetic energy threats.

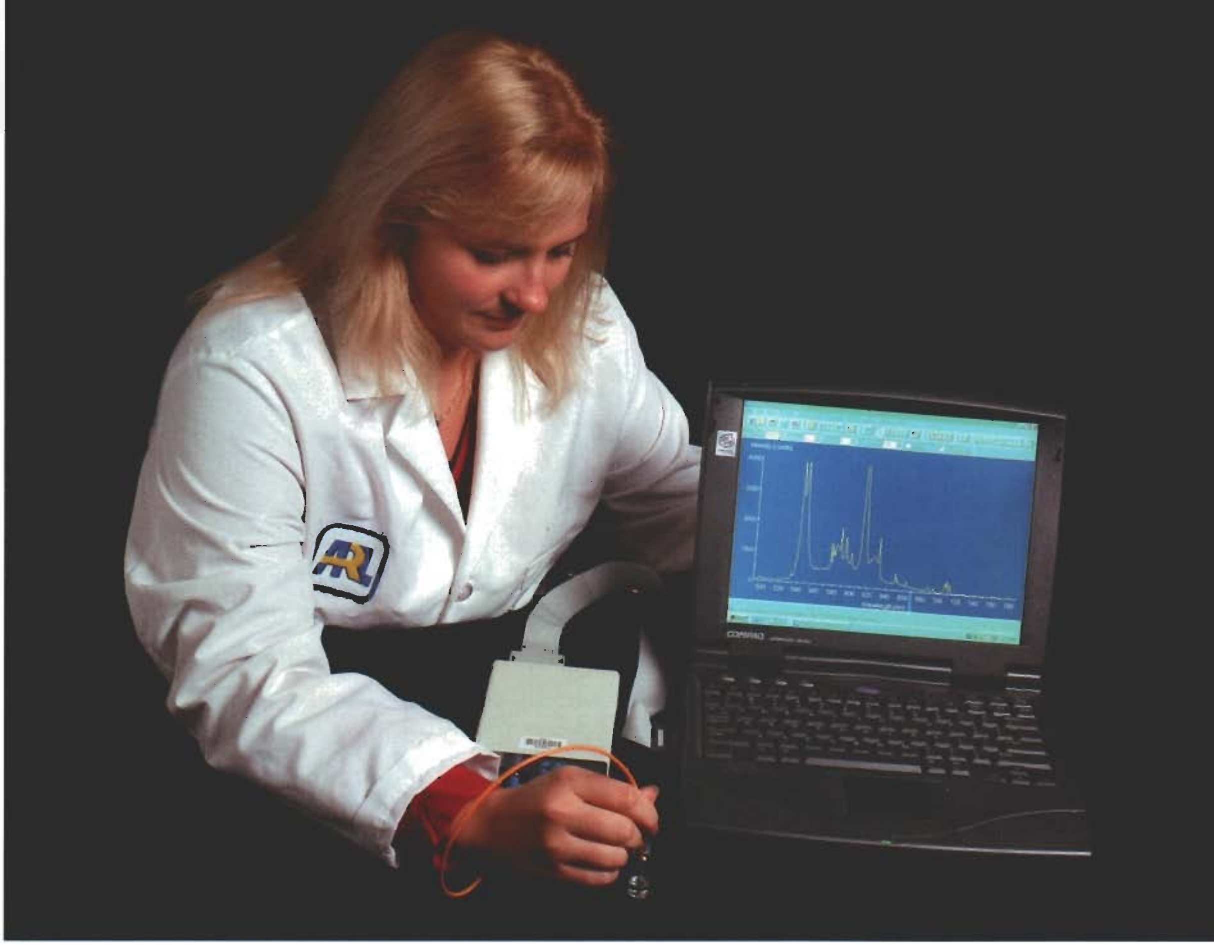
The Human Research and Engineering Directorate (HRED) ensures that soldiers can operate effectively on the high-technology battlefield with enhanced survivability in its lethal environment, while reducing their equipment weight and workload. Formed from the former Human Engineering Laboratory (HEL) and parts of the U.S. Army Research Institute (ARI), HRED combines the Army's human factors and Manpower and Personnel Integration (MANPRINT) resources at APG.

HRED executes a broad-based program of basic research and technology development with the objective of optimizing soldier performance and soldier/machine interfaces for maximum effectiveness. Extensive research in human perceptual, cognitive, and psychomotor performance builds the framework for human factors and MANPRINT advances, thus improving the effectiveness of fielded and developmental systems. HRED also provides Program Executive Office (PEO) Aviation with MANPRINT and Human Factors Engineering Support for the effective integration of aviation crews in the Comanche helicopter.

Headquartered at APG, MD, HRED also operates 21 field elements co-located at TRADOC Centers and Schools, AMC Research, Development and Engineering Centers (RDECs), and developmental and operational test centers. An estimated 30 percent of HRED staff is dedicated to understanding operational issues and addressing current and future human factors challenges with Army systems. HRED manages the Advanced Decision Architectures Collaborative Technology Alliance.

The U.S. Army Research Office (ARO) ARO has enhanced Army capabilities through scientific research for the past 50 years by selecting and funding basic research proposals from educational institutions, nonprofit organizations and private industry. Its research represents long-range Army views for technology changes.

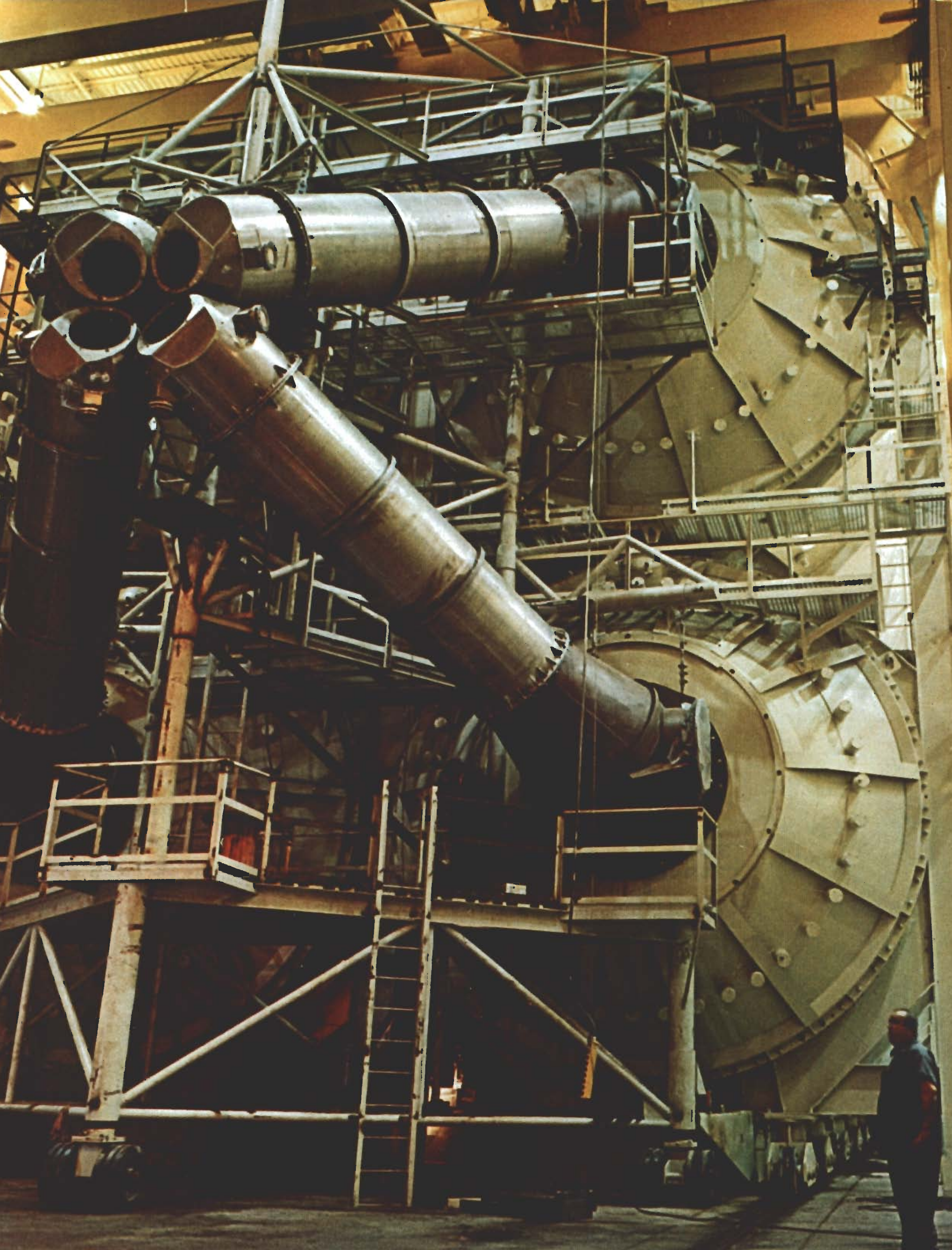




ARO competitively selects and funds basic research proposals from educational institutions, nonprofit organizations and private industry and is the only Army organization that transcends all of the military's mission areas: fire support, close combat, air defense, combat support, combat service support, soldier support, and command, control and communications.

The primary ARO program provides basic research that responds to the Army's operational requirements, while ARO's system of peer review and consulting with scientists successfully and consistently produces outstanding scientific work. Among the projects that ARO is currently supporting are a compact power source for an individual soldier to operate high-tech equipment; the integration of an electro-optical clothing system for climate control and protection and for monitoring the health and physiological conditions of a individual soldier, a patient or an athlete; the control and use of a single atom to detect underground structures from space; and quantum computing that will revolutionize computing as we know it.

Headquartered in North Carolina's Research Triangle Park, ARO also has offices in Washington and Tokyo with a total workforce of approximately 100 employees, including more than 40 scientists and engineers. ARO draws on the talents of experts at the University of North Carolina at Chapel Hill, North Carolina State University, Duke University and private high-tech organizations in the area.



Appendix II: Remarks at the 10th Anniversary Ceremony – October 10, 2002

Below are the remarks of Dr. Robert Whalin, Director of ARL, 1998-2002.

This is a great day for the Army Research Laboratory, a day to celebrate 10 years of contributions to the Army. I welcome each of you who have joined us for the occasion.

There are several people in the audience who deserve special recognition today. I would ask them to stand as I call their name.

An organization such as ARL could not exist without the support of advocates in the higher headquarters. We are delighted today to welcome Dr. William Berry from the Office of the Deputy Undersecretary of Defense for Science and Technology. From the Army Secretariat we have Mr. James Inman, the Department of the Army's Director of Acquisition Policy. And Dr. John Parmentola from the Office of the Deputy Assistant Secretary of the Army for Research and Technology.

ARL is the first step in the Army's research and development program. Our work has to be handed off to commodity commands, which translate our early efforts into items used by soldiers. A close tie and careful coordination with these commands is essential. We recognize several key officials from these commands: From the Tank Automotive and Armaments command-Dr. Richard McClelland and Dr. Walter Bryzik. From the Aviation and Missile Command- Dr. William McCorkle. From the Communications-Electronics Command- Mr. Walter Kasian. We also welcome Dr. Paul Dietz, the Director of the Army Materiel Systems Analysis Agency and Dr. Paul Ehle, Deputy Chief of Staff for Research and Development, Acquisition, and Science and Technology from the Army Materiel Command.

One of the hallmarks of ARL is the relationship with outside research activities such as universities and colleges and other federal laboratories. We have several attendees representing these constituencies: From the Institute of Advanced Technology at the University of Texas at Austin- Dr. Harry Fair. From the University of New Mexico-Dr. Arthur Guenther who is a member of our Technical Advisory Board from RCI, a consulting group that has been instrumental in helping shape ARL's vision–Mr. Steven Bills and Major General, retired, Ralph Wooten

I am particularly delighted to see so many retired ARL employees who have returned to share in today's proceedings. I would recognize: Mr. Bruce Fonoroff, Dr. John Frasier, Dr.




Wes Kitchens, Dr. Ingo May, Mr. Bill Mermagen, Ms. Renata Price, and Dr. Clare Thornton. Ms. Price was actually not an ARL employee but was at the headquarters of the Army Materiel Command. However, she was such a supporter of ARL that we will always consider her one of us.

The non-commisioned officer is truly the backbone of the Army. In our audience today we have: our present Sergeant Major, Enoch Godbolt, the Sergeant Major of the first battalion of the 216th Artillery, the unit that provides protection for ARL, Command Sergeant Major Glazner,

We have two of our retired sergeant majors with us: Sergeant Major James Tobiasz and Command Sergeant Major George Howell.

The 389th Army band under direction of Sergeant Justin Searle has made this morning a festive occasion with the spirited music.

In my time as the director of ARL I have been strongly impressed by the support of our local congressional delegation. We have a representative of Senator Sarbanes with us today: Ms. Jeanie Lazrod, his field representative.

We are particularly delighted that Mr. Thomas E. Dernoga, the council member from district one to the Prince George's County Council could join us today.

You will hear later in the ceremony the several reorganizations of units that eventually led to ARL. The major unit immediately preceeding ARL was the laboratory command. We have the last commander of the laboratory command, retired Major General Patrick Kelly. Mr. Richard Vitali was the first acting director of the Army Research Laboratory. We owe much to these two for passing the command baton that led to ARL.

The most important participants at today's ceremony are the workforce of ARL. Would all of the present employees of ARL please stand to be recognized? Thank you.

I have a friend who was telling me about the birthday party of his 10-year-old grand daughter. He related the excitement of seeing her at birth for the first time and the satisfaction of watching her grow into a polished and vivacious young lady. He remembered the good times and the bad times of her life: of scoring the highest points in the regional diving competition, of not making the school soccer team, of winning three awards for academic achievement at the end of fourth grade, of bringing home a less than satisfactory report card in conduct, of friendships that appear liable to last a lifetime, of friendships that went bad. All the typical ups and downs of a 10 year old.

However, with all the looking back the thought that most struck him was the incredible future the 10 year old faced. She could be whatever she wanted to be: an astronaut, a doctor, a caring mother, a soldier, a teacher, a scientist or engineer, a writer or artist. And she could play these roles in a world perhaps different than we

know today. A world of: connection among people, knowledge at one's finger tips, opportunity for all, an environment shaped by sound uses of energy, a more informed and careful participation in public decision making. My friend's overwhelming emotion was to look with envy at the future the 10 year old will face, a future he will not see.

ARL is the birthday celebrator today. During the course of this morning we will reflect on the ups and downs of the first ten years. We will celebrate the joy of today and we will look with envy at the future that is beckoning.

There are employees in the audience who were in attendance at the birth of several of the ancestors of ARL. These ancestors are numerous and include such well-known organizations as: the Harry Diamond Laboratories, the Ballistic Research Laboratory, the Material Technology Laboratory. However, the ancestors also include organizations that are perhaps not as well known such as: Field station #1 (a part of the signal corps engineering laboratory) and the radio laboratory which began in 1917 in Camp Alfred Vail, NJ.

All of the ancestors eventually became the Army Research Laboratory in 1992 as a result of the Base Realignment and Closure (or BRAC) study of 1991. Most BRAC decisions resulted only in closing of posts, camps, and stations, closings that frequently left entire communities economically devastated.

However, BRAC 91 established ARL as the Army's central research laboratory. As one ARL employee described BRAC 91, "a BRAC success story — not just closure but consolidation and modernization — with world class staff and two major state-of-the-art research facilities."

Your ARL is a laboratory that is the Army's corporate laboratory and principal executor of the Army's basic research program. As such, innovation is a key. Innovation comes from a synthesis of ideas from diverse sources. Research excellence is a result of careful teamwork within ARL as well as interaction with the scientific community in other services and in academia.

Innovation is not useful if the ideas remain on the researcher's bench. There must be technology transfer, moving concepts out of ARL into the field. This technology transfer is a responsibility of each worker in ARL. These are themes you will hear from both of our principal guest speakers today.

Mario Puzo has given a bad name to "godfather" with his three movies on the mafia. However, as many of us realize godfathers play an important role in the life of our children. Frequently a godfather would be at a child's birthday. If we continue our analogy of a child's birthday, ARL has had several godfathers, officials who have nurtured, encouraged, and supported ARL through the years. Perhaps none have been more instrumental than the present commander of the Army Materiel Command, General Paul Kern. General Kern graduated from West Point in the class of 1967. He stood 135 out of a class of 583. 35 years later he basically stands

number one of a class of 583.

The West Point class of 1915 is frequently described as the class the stars fell on. Much the same could be described for the class of 1967. The Secretary of the Army, the honorable Tommy White, is a classmate of General Kerns. Also a classmate is General Montgomery Meigs, the commanding general of the United States Army in Europe (who graduated one ahead of General Kern). This illustrious class includes Lt. General John Caldwell, the principal deputy to assistant secretary of the Army for acquisition, logistics, and technology.

General Kern had two early assignments to Vietnam where he earned a silver star, a bronze star medal with the valor device, three bronze stars for achievement, three purple hearts and a commendation medal.

Following Vietnam General Kern entered a masters degree program at the University of Michigan, graduating in 1973 with masters degrees in mechanical and civil engineering. He followed this with a utilization assignment in the department of engineering at west point teaching cadets weapons systems engineering and automotive engineering.

General Kern, in his Army career, has been able to straddle both the research and operational streams of the Army. As examples of his research assignments he was the team chief, light combat vehicle team in the Office of the Deputy Chief of Staff for Research, Development, and Acquisition and was the program branch chief for the Bradley fighting vehicle systems in Warren, Michigan. He was also the military deputy to the assistant secretary of the Army for acquisition, logistics and technology immediately prior to his assuming command of the Army Materiel Command.

His operational assignments included command of the 5th battalion of the 32nd armor of the 24th infantry division, command of the 2nd brigade of the 24th infantry division during Desert Shield/Desert Storm, and assistant division commander of the 24th infantry division. As you remember the 24th infantry division was the unit that made the famous sweep around the Iraqi forces during the Gulf War.

In addition to his combat awards, General Kern has earned a Defense Distinguished Service Medal, an Army Distinguished Service Medal, a Defense Superior Service Medal and five Meritorious Service Medals.

General Kern has provided ARL a leadership climate that focuses on support of the soldier, a sense of mission and accomplishment, and recognition of the need for continuing innovation in pursuit of excellence.

We welcome you, sir, and Mrs. Kern to today's ceremony and look forward to your remarks.

Below are the remarks of General Paul J. Kern, Commander, U.S. Army Material Command

Thank you, Dr. Whalin. What a wonderful introduction.

I was a little bit worried when you got started, though. I was watching Father Vince over here, my mafia buddy from New Jersey, to figure out whether or not I was going to need some protection, and then I was watching Al Grum down here, if he was going to tell you the real truth about my story as a cadet and as an engineering instructor, but we will let all of those go.

It is wonderful to be here with all of you today, truly a remarkable day for the United States Army and portends great things for our future.

I was watching, as you were going through all of those introductions, the number of people who had been mentors, instructors in this crowd, people who have shown me the right way to do things and people who have clearly contributed to what we have in the United States Army today, those pieces of equipment and the processes that have kept our soldiers alive and made it the greatest Army that we have.

You are going to hear from some of our soldiers a little bit later about some of the things that they were able to do because of what you all have done for them.

At the same time, in this room today, we have our future and the ability to create for the young kids today who have yet to join our Army, the processes, the equipment, the organizations that are going to keep them alive and keep us secure in the future, and that is both a tremendous responsibility for all of you as well as a tremendous goal to have in front of you as to what you can do for our country.

This organization and its many different names and its growth in the past has contributed continuously to our Army. You are our change agents. You do make the difference, and it is tremendously exciting to be able to join you today in a tenth anniversary.

As we were listening to the fife and drum corps of the Old Guard, though, I was thinking about what technology is really all about. I read a book recently that some scientists are trying to recreate the cello with the precision of some of our greatest players in this country. It takes today a room full of computers and a bank full of speakers to equal one wooden instrument with strings. So that sort of tells us that we have a ways to go in understanding the physics of science and the world we live in and how we can apply it.

Then think about these young folks who were standing here, playing and entertaining you. They were instruments of war when they were created. They were the signals that worked on our battlefield. They worked through smoke. They worked at night, and not only did they provide you something that you could hear and see, you felt it.

Now, how many of us today with our science can produce something that you can feel and stir you on the battlefield as well as tell you

what to do? So the great challenges of our world are still out there to try to figure out how do you replicate what science can do through old instruments, fife and drum and bugle, and put that into today's world.

As we move into this world of information, we ought to take some lessons from what we just saw standing right there. It isn't all flat-panel displays that create the messages that we have to get across to people. Those young guys in combat have to operate in the dark when they are scared, cold and they're wet. They have to operate when the equipment doesn't quite work the way they expected it to, and when other people are throwing things back at them. So we have to consider not just the physics, but we really do have to consider the emotional part of what we are doing and how we use that part of science, that part of our human being, the heart as well as the brain and the feet, to make things work for us.

So the challenges that we see in the future are really represented right here by the past and how we are going to operate for these young folks and provide them the equipment that they need to be successful for our country, just as many of you have provided the equipment that allowed us to win in the Gulf, 12 years ago. We may be doing that again very shortly, and we don't know yet what is going to come after that. So we have to be prepared for the unknowns. We have to be prepared to take what is thrown at us and turn it around and make sure that we come out as the winners.

So, whether it is the new technologies, Robert and I spent an earlier time this week looking at nanotechnologies and looking at where will they lead us, but the question isn't the technology, whether it is MEMS or nanotechnology or fuzes or ballistic armor or new projectiles, or many other pieces of equipment that you are all working on. It is what is it that we can do for these young folks to make sure that they are safe and that they win and they provide the security of our country.

So your history has shown that you can do this and you can do it very well. Our challenge is to continue to do that in the future, to make sure that there are the new scientists that come to work here that can carry on what you all have done for the years ahead, and that they have the right skills. And we may not know all of those right skills today because we are looking at new emerging technologies in the bioengineering and nanotechnologies and all of these areas that are beginning to emerge. So we have to keep asking ourselves why are we doing the right things and is it going to give them the products that they need.

So all of these add up to a great challenge for us, but it is also a great celebration of what you have done, and so I am very, very pleased that we can join you today as we celebrate your 10-year birthday, and I will be even more pleased as we grow this institution and we increase the capabilities that we give our soldiers, that we truly figure out how to take 100 pounds off their back and

make it equal 15 — that was the challenge you laid out on Tuesday — and how we can make power sources and how we can make survivability of our soldiers something which is easily worn, easily carried into the battlefield.

I know that you all have that capability. You have demonstrated it, and I look forward to joining you in the future to celebrate many more of these birthdays as we look to that future.

Thank you.

Dr. Whalin:

If General Kern can be described as one of the godfathers for ARL, then our next speaker, Mr. George Singley, can well be described as the attending physician. Mr. Singley was the Deputy Assistant Secretary for Research and Technology and Chief Scientist of the Army at the time of ARL's creation.

Mr. Singley had come to that job after several years of experience in the Army's aviation research and development community. In his job as the Deputy Assistant Secretary he supervised the entire scientific and technical program of the Army. This included 21 laboratories and centers with approximately 10,000 engineers and scientists and an annual budget in excess of 1.4 billion dollars. He had the dubious honor of supervising four rounds of base realignment and closures for the Army, one of which, as previously noted, included the creation of ARL.

Mr. Singley did not see the closures as the end of something. He had the foresight to see what could be, what could be positive from the closures. He provided the vision, the leadership, and the wherewithal, to make a purse out of what many would consider a sow's ear.

Through it all Mr. Singley exhibited remarkable good humor, a strong grasp of science and technology, and a caring attitude toward the Army research and development work force. There is an old cliche of "a gentleman and a scholar." George Singley was indeed a gentleman and a scholar, one who was instrumental in leading us to this occasion today.

Mr. Singley left his Army position in 1995 to become the principal deputy to the Director of Defense Research and Engineering. In this position he was responsible for defense science and technology strategic planning, allocation, execution, evaluation and ensuring that national defense objectives were met by the 7 billion dollar per year Department of Defense science and technology program. He was responsible for the oversight of all federally funded research and development centers.

Mr. Singley's last position with the Department of Defense was the Acting Director of Defense Research and Engineering where he was the chief technical advisor to the Under-secretary of Defense for Acquisition and Technology. Concurrent with these duties, Mr. Singley was also acting assistant to the Secretary of Defense for nuclear, chemical, and biological defense programs.

Mr. Singley became the President of Hicks

and Associates in 1998 following 33 years of dedicated service to the Army and the Department of Defense. He continues his contributions to the defense of this country as Hicks and Associates provides consulting services to the government as well as industry.

Mr. Singley, you honor us with your presence.

Below are the remarks of Mr. George T. Singley, President, Hicks and Associates:

General Kern, Dr. Whalin, other distinguished guests and members of the Army's premier research laboratory, I'm honored to participate in this celebration of your tenth anniversary, your exceptional public service and important contributions to our nation's defense.

This morning I will share with you my recollection of the original vision for ARL and the challenges I believe you will face in your second decade.

First...Congratulations! ARL and the Army S&T community have accomplished much in the last decade. ARL today is the descendant of a long line of innovative and productive laboratories. While at Watertown Arsenal (founded in 1816), the oldest ARL predecessor organization, General Rodman made major original contributions to cannon metallurgy ca.1860. Noting more recent significant accomplishments: the Harry Diamond proximity fuze in World War II; ENIAC the world's first programmable digital computer needed for efficiently producing firing tables; the sophisticated armor of the Abrams tank; and the M829A2 tank round known as 'the silver bullet' of Desert Storm fame. These are just a few notable achievements for which your predecessor organizations have made essential technology contributions.

ARL's first decade has been marked by startling world events, and breakthroughs in science and technology. The three key international events affecting ARL's first decade were the end of the Cold War, Operation Desert Storm, and, of course, the terrorist attacks of September 11, 2001.

The world marveled about the courage, daring, professionalism, proficiency and winning technological edge of our forces during Operation Desert Storm. The critics of the 1970s and 1980s who condemned the "Big Five" of Abrams, Bradley, Black Hawk, Apache and Patriot were proven wrong. Those of you who contributed the technology and engineering talent to create these systems can be justifiably proud of their unprecedented lethality, survivability and overall performance when the most important scorecard of all was delivered. The grade was swift victory and many fewer casualties than the pundits predicted.

Desert Storm also gave us a glimpse of a few revolutionary concepts and technologies: GPS, laser-guided weapons, JSTARS, night vision, stealth and unmanned aerial vehicles. All played key roles in the swift defeat of Iraq's forces.

The Gulf War also pointed out areas requiring

improvement with the aid of technology: mobile communications, command and control on the move, defeat of critical mobile targets, hard and deeply buried targets, joint warfighting, remote sensing of weapons of mass destruction, and the lack of survivability and firepower of our early entry forces.

Not withstanding the success of American weapon systems and technology witnessed on the evening news during the Gulf War, the allure of a post-Cold War peace dividend proved irresistible. Support for military science and technology funding and the service laboratories waned both in the Pentagon and in industry. There was growing criticism of the DoD laboratory system that was perceived as too large, unaffordable, inefficient, aging and unresponsive to the needs of the warfighter.

Funding for S&T and the laboratories was slashed. Downsizing the Army resulted in a drastic reduction in service members assigned to the laboratories. This I believe has exacerbated the decline in understanding of and appreciation for the importance of Army S&T and laboratory investments. It also has hurt the laboratory's ability to develop and articulate the military potential of advanced systems and concepts.

To accomplish the needed infrastructure reduction, Congress passed the Base Realignment and Closure Act. The 1991 BRAC Round disestablished the former Laboratory Command and consolidated several Army corporate laboratories at numerous sites into ARL located at the two principal locations, Adelphi and Aberdeen Proving Grounds. This followed an extensive debate as to whether the Army needed a corporate laboratory or should simply rely on the RDECs, industry and academia.

Critics of the DoD laboratories at the time argued that there was too much redundancy in the Service laboratories and that the S&T performed in house was not competitive with that provided by industry, academia, FFRDCs or the National Labs. An inflexible personnel system, antiquated laboratory facilities and outdated equipment were serious barriers to recruiting the best technical talent. OSD seriously considered consolidating all the Service labs into a Defense Research Organization. Project Reliance, the creation of the Service S&T Executives and, even to some extent the creation of the ARL, were a response to this challenge.

Why was ARL developed as the Army's sole corporate laboratory? ARL was founded on the vision that it would be the premier land warfare research laboratory, focused on high-quality, well-focused basic and applied research. The Army needed a unique research and technology competence that no one else would sponsor. Research was becoming more multi-disciplinary, and several strategic research areas were emerging that would benefit multiple Army RDECs and PEOs. Finally, ARL was intended to leverage the emerging commercial electronics, telecommunications, internet and computer revolution.

To prevent insularity and assure the highest



quality research, work would be performed in an open laboratory environment with increased on-site and off-site university, non-profit and industry researchers. ARL was organized and research focused along a limited list of technologies deemed most important to the Army of the future that would not be realized without Army investment and in-house research.

At the conclusion of Desert Storm, Mr. Vic Reis, then DDR&E told me of an exchange he had with then Secretary of Defense Dick Cheney. Marveling at the success of our forces and the technology that performed so magnificently during Desert Storm, the Secretary of Defense turned to Vic and inquired, "What will be our legacy?"

Well, today's forces are making good use of the legacy of the S&T community of the last decade. Since ARL's founding in 1992, you have achieved much.

You and your industry and university partners contributed to the technological foundation for a digitized Army capable of unprecedented battlespace understanding, synchronization and precision fires. General Sullivan, the CSA at the time, explained digitization in terms that any soldier and enemy can understand: "I know where I am, where you are and I am coming to defeat you". Digitization was an important first step toward the Army's current transformation.

You have gained two world-class laboratory facilities, one here in Adelphi and the other at Aberdeen Proving Grounds.

Cooperative research agreements and the acclaimed Federated Laboratory initiatives have reduced insularity, increased intellectual competition and spurred research progress relevant to the Army of the future. You focused the Federated Laboratory on research critical to achieving digitization.

When the Army and industry were wrestling with how to rapidly establish the battle laboratory system and embark on warfighting experiments, the Army Research Office led by Gerry Iafrate and ARL led by John Lyons responded with the Advanced Concepts Technology II program.

You have been a responsible steward of the taxpayer's hard earned money, providing invaluable "smart buyer" services to the requirements and acquisition community. As such you have protected the soldier from mediocre technology and systems.

The world changed again on September 11, 2001 with the first attack against the mainland US since the War of 1812. We witnessed the professionalism, courage and sacrifice of the first responders, our military and other citizens. September 11th showed the need to get on with improved homeland security, deal with the transnational terrorist threat and solve the glaring Army shortfalls experienced in Bosnia —some of which we identified in DESERT STORM but had not been fixed.

Our light forces are rapidly deployable, but too vulnerable and lack lethality. Our heavy forces have too large a logistical footprint and can't get to the fight fast enough. Army

relevance to the new world is at issue. As the CSA, General Shinseki, said to the Army "If you do not like transformation, you will like irrelevance even less". The ongoing Army transformation born in 1999 gained many more proponents and a new sense of urgency on September 11th.

As Secretary of Defense Rumsfeld noted, Afghanistan gave the nation a glimpse of transformation. Small units, Special Forces, using range finders, GPS and SATCOM were able to bring responsive joint fires including JDAM GPS guided bombs from loitering bombers. Hellfire missiles were fired from Predator UAVs with deadly effect. Improved situational awareness and battlefield visualization contributed enormously to the swift coalition victory over the Taliban and Al Qaeda. Soldiers scouted caves and tunnels using small robots.

Transformation is hard, but necessary. As General Shinseki has said: "You can't wring your hands and roll your sleeves up at the same time." The Army is rolling its sleeves up and grappling with transformation and the war on terrorism. ARL has the talent and imagination to be a major contributor to Army transformation.

In conclusion, I offer five keys to meet the challenges and seize the opportunities of this coming decade.

The first is ***Focus***. Army research sponsors, the acquisition community and warfighters will insist, and properly so, that ARL's research be: Of the highest quality, focused on areas unique and essential to success in future land warfare, and restricted to projects that will not get performed without Army funding. Your budget is finite and your mission too important, for any other approach. Laboratories that successfully feed the evolutionary acquisition of the capabilities required by the Objective Force will thrive.

Second, ***Avoid Insularity***. ARL was founded on the vision of an open laboratory. Visiting researchers from industry and academia are important to innovation and quality. More military personnel are needed in ARL to provide the user perspective. Collaboration with other laboratories, RDECs, industry and the customer is essential. Advanced systems and concepts are vital to innovation, focusing your investments and promoting the potential of your work. As Einstein said, "Imagination is more important than knowledge." Insularity will stifle imagination, innovation and your ability to be a smart buyer.

Third, ***Think Integration***. Increasingly, the key role will be in integrating technologies that already exist in industry and elsewhere, rather than developing new systems based on untried component technologies. Laboratories must help program managers to be smart buyers. The combination of advanced technology demonstrations, experimentation, collaborative environments, modeling and simulation can cut in half the time to define and develop weapons and systems of systems. Live, virtual and constructive simulation like that employed by the Joint Precision Strike Demonstration facility at Ft.

Belvoir will give confidence to the value of novel approaches and help define realistic requirements for affordable systems.

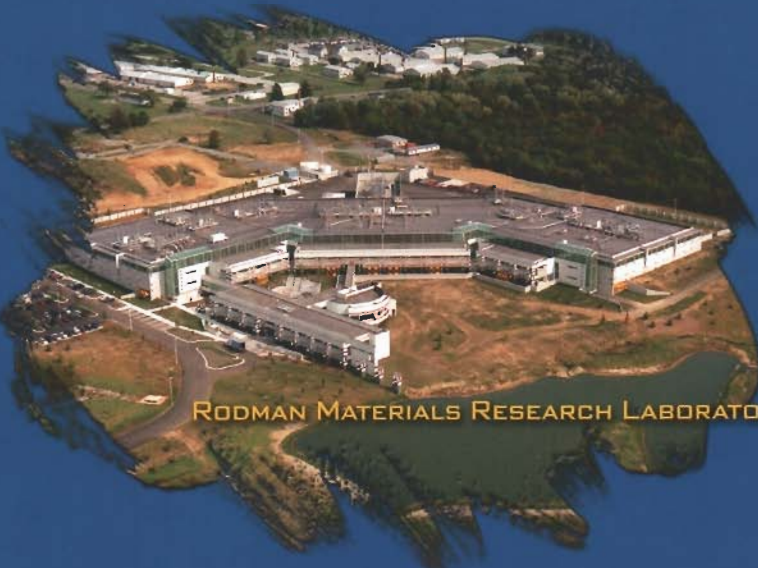
Fourth, ***Urgency.*** Time Matters whether you are talking network centric warfare, precision strike, precision logistics or acquisition. The old serial requirements and acquisition process is too long, too costly and ineffective against current and future threats. Terrorists and rogue nations will not follow our Cold War processes for requirements development and acquisition. They will use available advanced technology products and tactics to attack us asymmetrically. Time matters. Defense acquisition policy now calls for evolutionary, block improvement acquisition with spiral development of doctrine, organization, operational and systems concepts, requirements, systems and training. I believe this will require a significant change to S&T investment strategy, culture and ARL.

Finally, ***Outreach.*** Tell your story. Ignorance about past contributions and current efforts of our laboratories fosters a lack of support for laboratories and S&T. Outreach and promotion of your contributions to past, current and future readiness is vital to your future.

It has been my experience that scientists and engineers work for the Army because they want to make a difference. Your record at ARL is a distinguished one. Your first decade has been marked by innovation, technical excellence and dedication to public service and the soldier. With the pace of technology, challenges of transformation and your record of innovation and agility, the future looks bright for ARL.

Thank you again for inviting me to share in the celebration of your first decade as the Army Research Laboratory.


ADELPHI LABORATORY CENTER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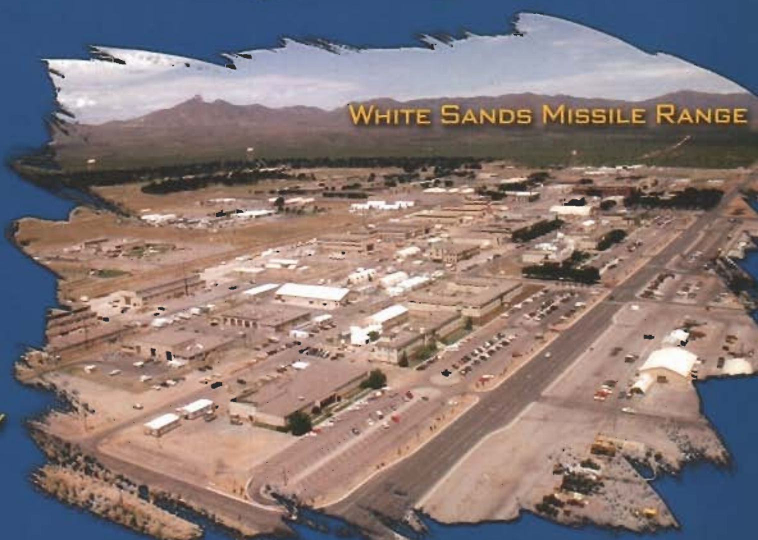
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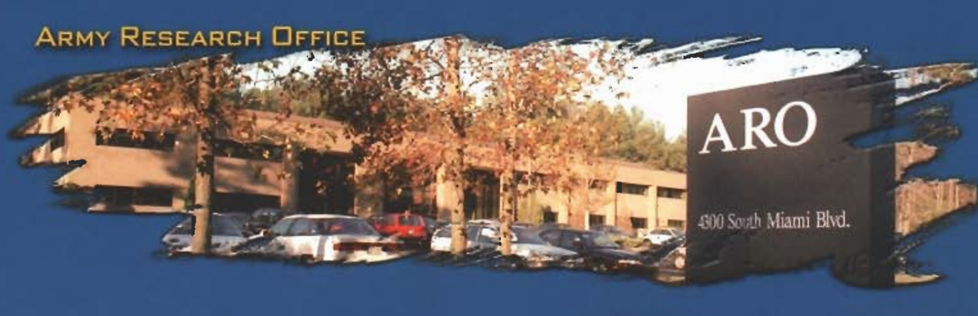

ARMY RESEARCH OFFICE