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Executive Summary for FY93

US Army Corps of Engineers
Construction Engineering Research Laboratories

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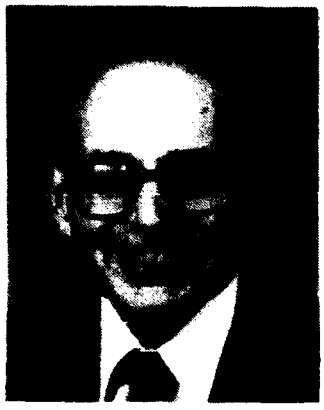
Dr. Louis R. Shaffer
1928–1994

USACERL
July 1994

Director's Statement

The ongoing Department of Defense (DOD) focus on the strategic military principles of deterrence, forward presence, crisis response, and reconstitution has moved the Army toward a new paradigm for its military installations, in terms of mission and functions. The implications for garrison commanders—not to mention our soldiers—is profound.



Dr. L.R. Shaffer

Commanders must achieve their missions while working under the growing pressure of deteriorating infrastructure and diminishing resources; almost 40 percent of the facilities are over 35 years old, and over 30 percent of the total are considered substandard. At the same time, growing concern about environmental pollution by all levels of government can encumber the commander's access to crucial training resources, and can present liability risks. For 25 years, USACERL has helped installations manage their built and natural environments more effectively with practical, affordable, timely, mission-enhancing sustainable products and services. USACERL's mission (ER 10-1-26, February 1992) is central to the National Military Strategy—to enhance Army training and readiness through research/development and technical assistance for affordable:

- *infrastructure acquisition and revitalization*
- *installation management and public works*
- *energy conservation*
- *environmental base operations*
- *technology transfer.*

Nobody else *anywhere* shares our unique mission. Private industry by itself has no inherent incentive to focus R&D on Army installation challenges, so USACERL initiates numerous partnerships with the nation's premiere industrial and academic institutions to address topics of mutual interest. Every year, products of these partnerships ripple into use, far beyond the military. I believe this report clearly illustrates how important USACERL is to the National Military Strategy—and why we were recognized this year as the Army Corps of Engineers Laboratory of the Year.

Dr. L.R. Shaffer
Director

Commander's Statement

This report summarizes the past year's accomplishments in research and development (R&D), technology transfer, strategic planning efforts, and Total Quality Management (TQM) initiatives by the U.S. Army Construction Engineering Research Laboratories (USACERL).

LTC David J. Rehbein

The list of accomplishments is impressive by any measure. Our mission is vital to maintaining a trained and ready Army. Our Army is threatened when training dollars must be diverted to necessary but expensive environmental compliance demands and the costs generated by an obsolete and aging infrastructure. USACERL R&D provides tools to conserve our dwindling resources through revitalization of installation infrastructure and proactive stewardship of our natural and cultural resources.

I do not want to recap the entire report in this brief space, but instead, to acknowledge the people who make things happen day after day. The advanced equipment and facilities are the media for our achievements. Our partnerships with the University of Illinois (and many others) energize our work, and stretch our resources far beyond what they could otherwise accomplish. But, all things considered, the USACERL staff is the ultimate source of our every noteworthy accomplishment. The abundance of capable, resourceful, and dedicated people at USACERL creates an almost electric sense of purpose and community.

We at USACERL have a simple vision for fulfilling our mission to the American soldier and the chain of command:

We will be the recognized leader for infrastructure and environmental research, development, and support.

The *words* are simple, at least. We all know that attaining the vision will be anything but simple. We composed our vision collectively, and accepted it by a very strong consensus. I am proud to be part of an organization with such people and such a vision.

David J. Rehbein
LTC, EN
Commander

Army-wide use of this USACERL-developed reed-bed sludge dewatering facility could save at least $1 million annually in O&M expenses.

I Accomplishments and Impact

Customer Satisfaction

Customer satisfaction has been considered a key indicator of USACERL's R&D success for years, but organization-wide attention on this metric has been sharply focused with the implementation of USACERL's Total Quality Management (TQM) initiative in FY91. A series of quantitative and qualitative customer satisfaction metrics are being developed as part of the corporate strategic and business plan (see Chapter II). A baseline metric of customer satisfaction is letters of appreciation received. USACERL researchers received 49 letters of appreciation from external customers and higher headquarters during FY93. Among others, letters were received from:

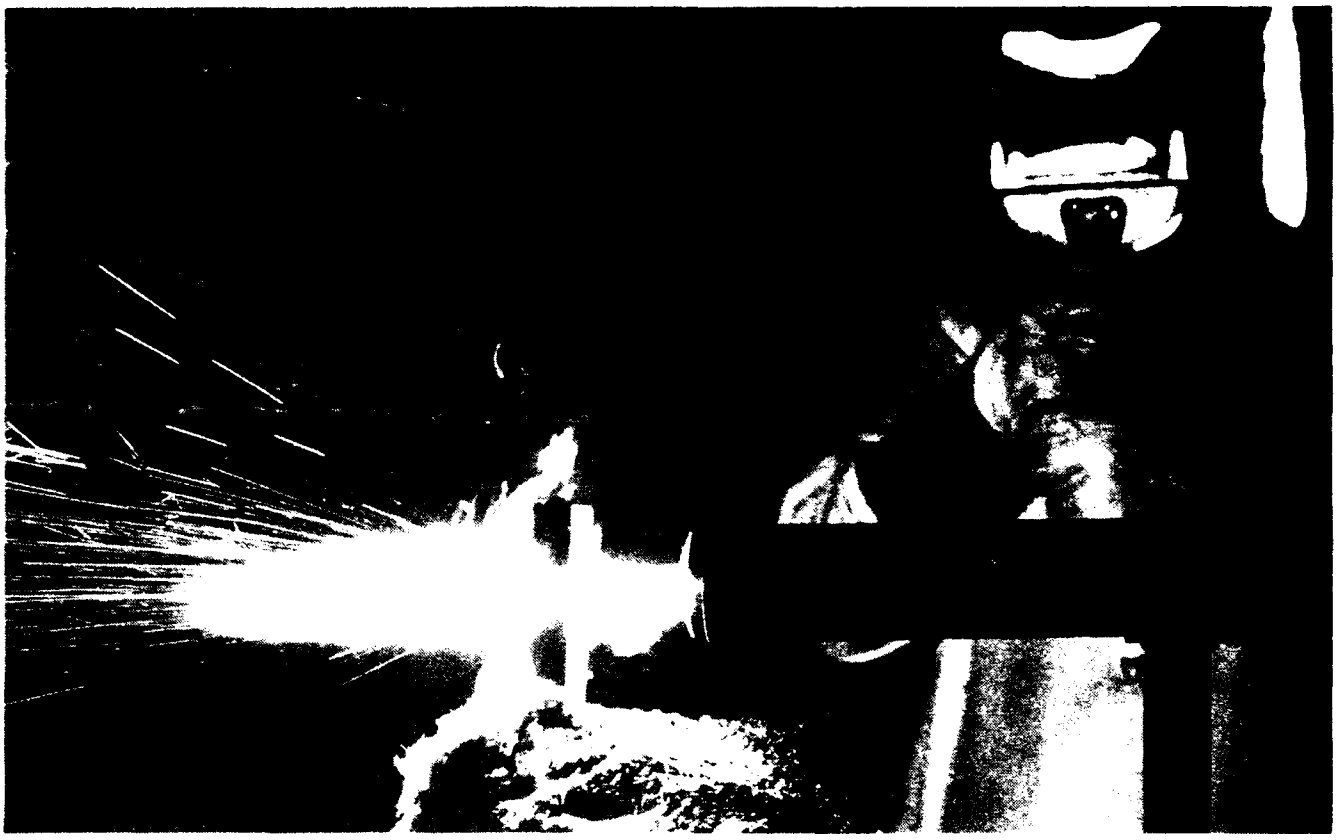
- Secretary of Defense Les Aspin, for winning the Federal Laboratory Consortium Award for Excellence in Technology Transfer—the sixth such award for USACERL
- Lewis Walker, Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health), for USACERL planning efforts for the Senior Environmental Leadership Conference
- Craig McFarlane, Senior Scientist, Environmental Research Laboratory, USEPA, for supporting a major global warming study with USACERL Land Condition Trend Analysis data and interpretation
- BG Russell Fuhrman, HQ USAREUR, for support of the USAREUR Environmental Review Training Guide Seminar
- Patrick Meehan, Principal Director, Office of the Deputy Assistant Secretary of Defense (Environment), recognizing USACERL contributions to two DOD environmental forums
- LTG Arthur Williams, Chief of Engineers, for USACERL contributions to DOD environmental forums
- Dr. Robert Oswald, Chairman, Joint Engineers Management Panel, USACE, for USACERL's "superb" contribution to the Tri-Services Environmental Quality R&D Strategic Plan program review
- MG John Sobke, Assistant Chief of Engineers, for USACERL R&D leading to a facility evaluation methodology that will "return dividends as the Army downsizes."

Meeting Assigned Objectives

USACERL is the assigned lead agency for two Science and Technology Objectives (STOs) in the *Army Science and Technology Master Plan* (Environmental Compliance [VI.C.12] and Environmental Conservation [VI.C.13]). In Project Reliance, USACERL is the assigned lead for six sub-subareas under Civil Engineering and six sub-subareas under Environmental Quality. (See "Lead for Joint, Multi-Service, and DOD Wide Programs" later in this chapter.)

Of the eight National Military Strategy goals articulated in *Installations—A Strategy for the 21st Century* (pp 12–19), USACERL's R&D supports *seven*. FY93 accomplishments are discussed in the sections that follow, categorized by STO and applicable National Military Strategy installations goal.

To fulfill its assigned objectives for FY93, USACERL had 1,261 sponsor and product milestones scheduled. Of this total, 1,104 were met on time. Seventy-three more were met during the year, but off-schedule. *USACERL's total percentage of milestones met in FY93 was 93.3 percent.*



USACERL is investigating plasma arc torch applications to render asbestos-containing waste materials harmless. This technology can eliminate the cost of special transportation and disposal of asbestos wastes, and save the Army millions in potential liability costs.

Compliance STO

Army Air Pollution Emission System. To ensure stewardship and avoid liability for regulatory noncompliance, installation commanders need a system to effectively capture data, track trends, and provide decision support. In joint work with the Navy, USACERL developed the data-entry tool that will enable contractors to more easily compile air emissions data for Army installations. This tool is an important component of a planned total management system to automate recordkeeping, provide tracking and decision tools, and automate emission factor calculations.

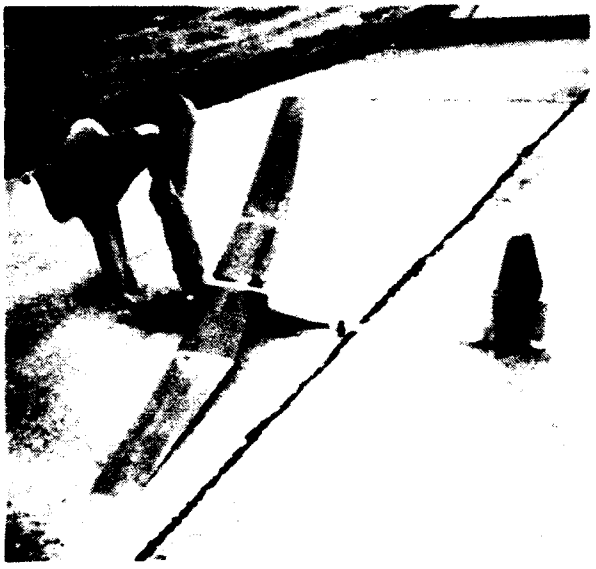
Ordnance Disposal Methods. Destroying demilitarized munitions and waste products by open burning/open detonation discharges uncontrolled emissions into air and soil. Installation commanders are legally liable when these emissions violate environmental laws. Of five environmentally friendlier alternative disposal methods researched by USACERL, hydromilling was identified as the most promising. This technology uses a high-pressure water jet to safely cut up bulky energetics. A hydromilling pilot plant constructed in FY93 is being field tested by the Lone Star and Radford Army ammunition plants.

Reed Bed Sludge Dewatering. With Army-wide application, a USACERL-developed sludge-dewatering technology could generate net O&M savings of at least $1 million annually after payback. Conventional sand drying beds used to dewater sludge at Army wastewater treatment plants (WWTPs) need large operating areas and have long dewatering times. USACERL developed a modified bed planted with reeds that keep the substrate loose for water passage and dry the sludge through evapotranspiration. The estimated payback period for this reed bed is less than 3 years; one at Fort Campbell, KY, should save approximately $20,000 annually on sludge removal, transportation, and disposal costs.

Firing Information and Range Execution System. Weekend residents, resort owners, and local elected officials have tried to close Camp Grayling, MI, a National Guard post adjacent to wildlife preserves in upper Michigan, because of low-frequency impulse noise from tank gunnery, artillery fire, explosives, and demolition. Ac-

cording to BG Jerome J. Mathiew, Jr., MI ARNG, "noise has the greatest potential, in my opinion, to eventually shut down or severely curtail necessary training across the nation." In FY93, USACERL installed key components of its Firing Information and Range Execution (FIRE) system at Camp Grayling Range Control. The system has monitors throughout the range and airport to help installation trainers and environmental managers plan training, manage day-to-day noise concerns, and better respond to community inquiries. After a year of operation, noise complaints about Camp Grayling dropped 90 percent. BG Mathiew applauds the USACERL research team "for its very necessary lead in this vital part of today's coexistence with the environment we are all trying to preserve."

DECIM. The Army is the designated lead agency for support of the Defense Environmental Corporate Information Management (DECIM) system. USACERL's Army Automated Environmental Management Information System (AAEMIS) was the first software selected for inclusion in DECIM. AAEMIS was upgraded by USACERL in partnership with the University of Arizona. Crucial meetings of top environmental engineers (GS-11 up to SES) used to take 15 weeks. The software upgrade reduced the process to only 4 weeks while ensuring full expert participation. The DECIM functional areas analyzed this year include hazardous substance management, pollution control and abatement (A-106), compliance deficiency tracking, and cleanup project management. Other USACERL systems selected as initial DECIM systems include HAZMIN and DENIX.



USACERL is applying this Navy-developed drone aircraft technology to monitoring protected habitats and archaeological sites on Army installations.

DENIX. In FY93, USACERL launched its Defense Environmental Network and Information Exchange (DENIX) environmental bulletin board system, which integrates data and online services from eight other bulletin forums, eliminating redundancy, reducing costs, and saving users' time. DENIX, which was based on USACERL's Army Defense Environmental Electronic Bulletin Board System (ADEEBS), supports environmental compliance by providing data, file-transfer capabilities, electronic conferencing, and other capabilities, for which some DOD installations had previously paid up to $8,000 a year to commercial vendors. Through DENIX, all DOD installations and activities can access the EnviroText Retrieval System (ETRS), a vast online library of government environmental laws, regulations, executive orders, etc., and other essential documentation. In its first month of operation, DENIX recorded more than 3,500 login sessions, with 425 users.

Underground Storage Tank Locator. This instrument, developed by USACERL in cooperation with Geophex, Ltd., will help the Army avoid related cleanup and liability costs by finding underground storage tanks (USTs) whose location is no longer on installation records. This accurate, reliable hand-held electromagnetic sensor locates USTs by detecting conductivity differences between materials and the surrounding soil. In a June 1993 test at Fort Belvoir, VA, the instrument quickly located an aging UST whose location had not been tracked through the years. It can also detect contaminant plumes leaking from a damaged UST. Quick detection of untracked USTs will enable Army users to proactively maintain or properly dispose of USTs before they become a compliance liability.

Conservation STO

ITAM. Installation managers at more than 40 major training bases use USACERL's Integrated Training Area Management (ITAM) system as a proactive approach to avoiding not only the cost of land restoration—$250 to $5000 an acre—but also noncompliance fines, litigation, and loss of access to training resources. DAIM-E has endorsed ITAM as "the Army's integrated approach to land-use management." In FY93, the ITAM program was moved from the research environment to full operational application.

Carrying Capacity. The Tracked Vehicle Day (TVD) value measures a land's carrying capacity to withstand vehicle traffic. In FY93, USACERL researchers completed a conceptual model that calibrates the Universal Soil Loss Equation with LCTA data to provide the TVD. The model is significant because it provides a common denominator for translating ecological data into a form compatible with land management. Also during FY93, research progressed on the quantification of maneuver

damage, recovery of resources, and acceptable cover loss. In combination with TVD, this information will help increase training realism, minimize fines for environmental noncompliance, and improve Army stewardship.

Cultural Resources Conservation. Noncompliance with the National Historic Preservation Act cost the Federal government over $10 million in FY91. The Army established the Tri-Services Cultural Resources Research Center at USACERL to help military installations avoid fines, improve stewardship, and comply with historic preservation legislation. A cooperative agreement combines construction, environmental, and computer technologies developed at USACERL with preservation, artifact storage, and curation technologies to support the Tri-Services Environmental Quality Strategic Plan and the Army's Conservation STO. The Center creates methodologies for evaluating and managing cultural resources on a national scale. It also coordinates long-term, nationally oriented R&D for cost-effective DOD-level historic preservation planning. Services and activities completed, in progress, or in planning during FY93 included:

- an integrated cultural resources management system
- innovative technologies for recording historic objects and archaeological materials
- evaluation of the satellite-based global positioning system for archaeological survey
- subsurface modeling for archaeological site investigations on DOD lands
- layaway inspection and maintenance and repair (M&R) checklists for mothballed historic structures
- facilities pathology guidance (identify materials failures within historic structures)
- master specifications for historic preservation
- preservation technology sourcebook
- national inventory and evaluation standards for World War II structures (estimated cost savings of $5 million).

Strategic Installations Goal 1: Power Projection

Mobilization. USACERL's entire line of engineered management systems (EMSs) strongly support the power projection platform strategy. Rail lines and pavements are two of the most critical infrastructure elements supporting—or potentially inhibiting—mobilization. The Army owns more than 2800 miles of active railroad track and more than 197 million square yards of pavement (roads, airstrips, etc.). Power projection specifications demand effective maintenance of this strategic infrastructure, so installation managers must focus their limited M&R resources on the most critical needs. In FY93, USACERL released version 4.0 of the RAILER and version 1.0 of TRACK, two interactive EMSs that help M&R managers identify, analyze, and prioritize M&R needs. These systems help avoid costly reactive repair of inadequately maintained track, and injuries and damaged cargo due to derailments. Also released in FY93 was an upgrade of Micro PAVER (version 3.1), which includes a refined Pavement Condition Index (PCI) procedure and new features for interfacing with geographic information systems (GISs), spreadsheets, databases, etc. (Micro PAVER is further discussed under "Technology Transition.")

USACERL's leadership in lead-based paint mitigation will improve ways of removing this poison from aging Army buildings while keeping it out of the ecosystem.

Goal 2: Quality of Life for Soldiers and Families

Lead-Based Paint Removal. USACERL's research on lead-based paint (LBP) removal addresses a major quality-of-life issue under Goal 2 of the National Military Strategy. To more safely remove lead-based paint from wooden structures, USACERL researchers applied a special chemical stabilizer to sandblasting media in FY93, and tested it on structures at Fort Meade. Another innovative paint removal compound was evaluated at Fort Meade in FY93: environmentally friendly chemical strippers made from orange and lemon peels. These strippers could significantly reduce the Army's reliance on conventional petroleum-based solvents.

Encapsulation of Lead-Based Paint. USACERL has developed a vitrification process that immobilizes lead inside a glassy compound, rendering the lead harmless to humans and the environment. The product is a ceramic compound applied *in situ* by a flame spray process. After the lead is encapsulated, it will not leach into the environment—it is effectively no longer toxic. The process was extensively tested in the laboratory

during FY93 in preparation for field testing. It was also tested with chrome, and USACERL researchers believe the process can be used on cadmium and other toxic heavy metals.

Goal 3: Environmental Stewardship

All USACERL R&D and technology transfer being conducted under the Compliance and Conservation STOs strongly support the strategic environmental stewardship goal. Current R&D highlights are presented earlier in this chapter, under "Compliance STO" and "Conservation STO."

Goal 4: Investment for Quality Facilities

Renewables and Energy Efficiency Planning (REEP) Program. During FY93, USACERL developed REEP in conjunction with the U.S. Army Concepts Analysis Agency and the U.S. Army Center for Public Works. REEP integrates engineering, financial, economic, and operations research methods to evaluate energy system technology and conservation for large Army installations. According to the Deputy Under Secretary of the Army for Operations Research, REEP "makes a major contribution to the development and evaluation of a strategy for investment in energy efficiency and renewable energy at Army facilities." To date REEP has been used to evaluate 59 energy conservation opportunities across 110 installations. Ten energy conservation technologies with the highest potential for cost savings and pollution prevention were analyzed by the U.S. Army Concepts Analysis Agency to estimate the potential benefits. If these technologies were applied at 49 Army installations in the continental United States, the estimated cost savings, according to a REEP analysis, would be over $560 million, with emission reductions of over 6.5 million short tons.

Concurrent Engineering R&D. USACERL's concurrent engineering R&D initiative for the Assistant Secretary of the Army for Research and Development, known as Architect's Associate, will help the Army resolve problems caused by the fragmented, inefficient sequential process of facility design still prevalent today. Architect's Associate could:

- reduce design time and cost by 35 percent
- reduce construction costs by 9 percent
- reduce life-cycle costs by 25 to 35 percent.

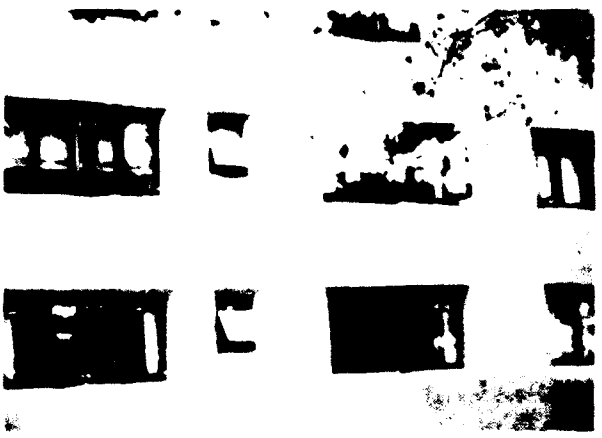
Concurrent engineering enables all stakeholders to execute design decision processes concurrently. It supports teamwork and group decisionmaking, which results in optimized facility design, and brings life-cycle cost reduction issues to the forefront of the design process. Finally, it creates robust, integrated model representations that can evolve rationally throughout the facility design process.

Designer Software. The goal of Designer Software, a product of the Architect's Associate initiative, is a tenfold reduction in Army facility design costs. Designer Software is an "agent-based" software environment that integrates diverse design tools and documents such as computer-aided drafting systems, bid specifications, design databases, and analysis programs. Agents are small expert systems that communicate using libraries of design objects. They can operate in the background to provide the designer advice. USACERL released the first MS Windows™ version of Designer Software to Mobile District in FY93, and continued work on a version compatible with Intergraph's MicroStation CAD package running under MS Windows NT. *If Designer Software were now used in 5 percent of the Army's new construction design work, it would save $2.7 million annually.*

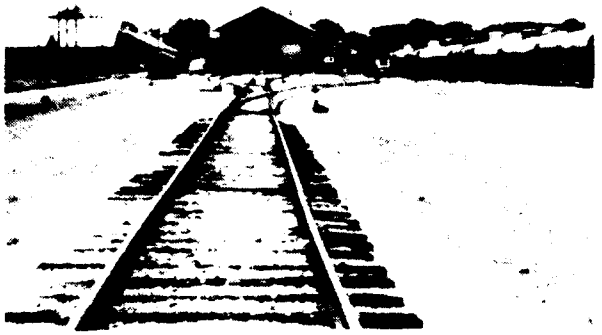
Triaxial Shock Test Machine (TSTM) Upgrade. Weapons-effect and seismic R&D for equipment and structures are indispensible to the Army's mission. USACERL's Biaxial Shock Test Machine (BSTM) is the most capable in the western hemisphere in terms of acceleration and frequency response. But the United States has no triaxial facility for testing large items, while several foreign nations do. In FY93, USACERL awarded the contract to upgrade the BSTM into a triaxial unit, saving the Army almost 60 percent of what it would cost to build a new facility from the ground up. Construction is set to begin in the second quarter of FY94. When completed, the TSTM will be the only large triaxial shaketable in the nation. R&D conducted on the TSTM will reduce the shock-related vulnerability of U.S. and NATO facilities, sensitive equipment, and lifelines. With its enormous potential for industrial applications and basic research, the TSTM will be known as a major U.S. research asset.

Goal 5: O&M Cost Reduction

Robotics. Robotics technologies are expected to dramatically reduce inspection and quality control costs, both for existing infrastructure and for new construction. USACERL's Robotics Technology Center, established in FY93, has already conducted joint studies with DOD agencies, Federal laboratories, universities, industry, and end users to produce several prototype robotics platforms. The CERLARM prototype—a long-reach robotic arm—is being evaluated in two Construction Productivity Advancement Research (CPAR) projects: (1) a robotic inspection system for *in situ* inspection of above-ground fuel storage tanks, and (2) the Mechani-



Specifications developed by USACERL for insulated external cladding (above) are under consideration for adoption as a national standard. USACERL-developed EMSs track and prioritize the M&R needs of railroads and other critical Army mobilization assets (below).



cally Aided Mason's Assistant (MAMA), which helps masons place concrete block with much less physical exertion and risk of back injury.

Another USACERL prototype is CERLBOT, an unmanned ground vehicle fitted with sensors, a manipulating arm, and controls for both autonomous and remote operation. Potential applications include soil moisture sampling, revegetation and reseeding, grass cutting, detection of unexploded ordnance at training ranges, sampling of toxic spills and emissions, asbestos and lead-based paint removal, roof inspection and cleaning, pavement and track inspection, physical security, and surveillance.

Composites. The cost of repairing or replacing deteriorated metal, wood, concrete, and steel in waterfront structures in the United States is estimated to be more than $125 billion annually. The creosote-treated lumber and old steel removed from these structures also pose environmental hazards and special disposal costs. USACERL is conducting research with the Composites Institute and others to produce cost-reducing, high-strength hybrid composite alternatives to traditional materials. For example, USACERL is investigating glass fiber reinforcement rods to replace steel in concrete structures: the composite will not rust like a steel rebar, requires no cathodic protection, and will not cause concrete to flake off the structure. Because the material will not deteriorate in water, USACERL is also investigating it to eliminate the considerable cost of replacing rotted wood pilings.

Commingled Recycled Plastics. USACERL led a consortium of universities, private-sector organizations, and government agencies in an ambitious CPAR project to develop durable, innovative building materials made from mixed recycled plastics. These materials will reduce the need for replacing components in wet or corrosive environments. Plastic lumber and other such materials also support Army environmental stewardship by diverting plastic refuse from landfills to constructive use.

Smart Materials and Systems. A "smart" USACERL built-up roofing system developed in FY93 combines roofing materials with leak-detection sensors to instantly determine the location and severity of a roofing leak. Early detection and repair minimizes reroofing costs. USACERL also launched a Federal Small Business Innovative Research (SBIR) project on alloys that "remember" their original shape, and return to it after being heated.

Other technologies investigated by USACERL include piezoelectric and magnetostrictive materials, fiber optics, electrorheological/magnetorheological materials, and self-repairing systems. These materials can be embedded in structural components to sense—and even temporarily repair—damage. Potential applications for these smart materials include: structural damage control, strain reduction, shape control, seismic damping, self-erecting structures, and thermal safety devices.

Standards for External Cladding. Exterior insulation and finish systems (EIFSs) can enhance the appearance and energy efficiency of Army buildings. Their use increased dramatically in recent years, but often with unsatisfactory results. USACERL developed criteria for functional, long-lasting systems and published its findings in a draft Technical Manual: Exterior Insulation and Finish Systems. The document is now under field review before publication as an Army standard. The USACERL principal investigator on this project is a member of the American Society for Testing and Materials (ASTM) committee developing standards for

EIFS. The USACERL-developed criteria are currently in balloting.

Diurnal Ice Storage. Storage cooling technology, if used Army-wide, could save $5 million on power costs annually. USACERL's 10-plus years of storage cooling R&D has now moved heavily into transfer and implementation. In FY93, USACERL and USACE Savannah District designed a chilled water storage cooling system that will shift over 2 megawatts of demand from onpeak to offpeak periods. *The local electric utility company is supporting the design with an incentive award of over $700,000.* USACERL was also technical consultant for Fort Huachuca, AZ, where a 700,000 gallon chilled water cooling system was completed in FY93.

Goal 7: Decision Aids for Commanders

Integrated Systems Language Environment. USACERL's Integrated Systems Language Environment (ISLE) integrates five software technologies into one engineering environment. In FY93, the first phase of ISLE research developed the IMPORT/DOME language system (Integrated Modular Persistent Object Representation Translator/Declarative Object Manipulation Environment) which provides an environment for writing software to support diverse applications such as organization modeling, construction management, geographic information systems, and distributed combat simulations. ISLE has already been used to produce a flight simulator for the unmanned aerial vehicles discussed in the Leveraging section under "Spin-Ons."

Engineered Management Systems (EMSs). USACERL's suite of EMSs provide installation and garrison commanders critical automated decision aids addressing resource allocation and scheduling of M&R for all major installation components—roads, airstrips, roofs, coatings and paints, water supplies, etc.

The Army devotes about 55 percent of its real property maintenance funds to building maintenance alone. In FY93, USACERL completed a design prototype of an MS Windows version of BUILDER, which helps facility managers objectively evaluate the condition of building components. By coupling objective assessment with condition-prediction modeling, BUILDER will help installation managers develop M&R schedules that maintain buildings at an optimum condition for the lowest cost. USACERL will integrate its widely-used ROOFER and PAINTER EMSs into BUILDER to create a comprehensive program for building condition assessment and M&R budgeting. Several EMSs, including Micro PAVER and RAILER, have a long track record of use not only on installations, but also nonmilitary Federal agencies, state and local governments, and private industry. Other USACERL EMSs include:

- GPIPER, which predicts the corrosion status of gas distribution systems. During FY93, USACERL transferred GPIPER technology to Corpus Christi Army Depot, West Point, and Forts Benning, Drum, Jackson, and Riley.
- W-PIPER, an EMS that helps water system managers sort out the variables that govern M&R decisions
- CP Diagnostic, for cathodic protection systems
- BRIDGER, which applies the benefits of the EMS to tracking condition and scheduling maintenance for the Army's 1500 bridges.

Economic Decision Model for UST Management. This computerized model estimates the least-cost method of meeting Federal UST regulations. The decision hierarchy helps installation managers identify the least expensive alternative for sustaining or regaining regulatory compliance, helping the Army and other users avoid fines and penalties for noncompliance.

USACERL Technical Documentation

The following is a summary of USACERL product and system documentation published over the past two fiscal years:

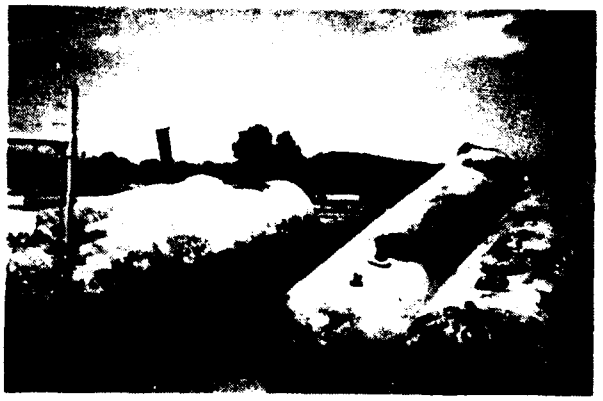
Type of Document	*FY92*	*FY93*
• Technical Reports	45	55
• Special Reports	7	14
• Interim Reports	8	8
• ADP Reports	11	6
• User Guides	7	4
• Technical Manuscripts	0	2
• REMR Technical Reports	2	2
Total	*78*	*89*

Also during FY93, USACERL processed 7 technical documents for publication by external military organizations (e.g., USACE Institute for Water Resources, Air Force Civil Engineering Support Agency, etc.), and produced 26 instructional and informational videotapes.

Technology Transition

Most of the transitioned products not highlighted in this section are discussed elsewhere in this chapter. The following lists show USACERL products and systems transitioned in FY93. The Infrastructure Laboratory transitioned:

- Civil Works Management Systems for valves and breakwater jetties
- Fingerstock Maintenance Guide for EMP-shielded facilities
- Micro PAVER 3.1
- RAILER 4.0



USACERL's TANKMAN helps installations more quickly prepare UST maintenance and management plans required by draft Army Regulation 200-1.

- ROOFER 2.0
- PAINTER 1.0
- Designer Software
- Boiler Plant Operator and Training Certification
- Photovoltaic Power Generation System
- IMPORT/DOME (alpha version)
- Embedded context-sensitive assistant for CADD users
- Prototype spatial grammar to generate controlled designs
- Theater Construction Management System 1.0

The Environmental Sustainment Laboratory transitioned the following:

- GRASS 4.1
- DENIX
- EnviroText
- TANKMAN
- Land Condition Trend Analysis (LCTA)
- GIS components of the Integrated Training Area Management system.

Micro PAVER PCI. In FY93, the American Society for Testing Materials (ASTM) adopted USACERL's pavement condition index for airfields as Standard Test Method D 5340-93. The Federal Aviation Administration also released advisory circulars AC 150/5380-6 and 150/5380-8, which recommend the use of Micro PAVER. More than 300 DOD, government, and private organizations in the United States and abroad currently subscribe to Micro PAVER.

GRASS 4.1. USACERL released the 4.1 version of its Geographical Resources Analysis Support System (GRASS) on an Internet file transfer protocol server. New capabilities include a GRASS-DBMS link to Informix, a graphical user interface, surface interpolation and modeling capabilities, enhanced visualization tools for the Silicon Graphics platform, and new tools for projection use/translation. Twenty-six new programs were added and ten existing programs were significantly enhanced. A GRASS shell-script command and electronic mail address were initiated to formalize reporting GRASS software bugs. Since its initial release, three update packages for GRASS 4.1 have been added to the source code.

TANKMAN. This USACERL product, transitioned in FY93, is a UST inventory database that uses a calculated leak potential and other factors to generate condition reports for Army USTs. TANKMAN has been distributed to all major Army commands (MACOMs) in the continental United States, and to the Eighth U.S. Army, Korea. Draft Army Regulation (AR) 200-1 requires installations to provide UST maintenance and management plans using Army Environmental Center (AEC) software, including TANKMAN.

Breakthroughs

As noted by the Army Research Office after thorough review of USACERL's basic research program in May 1993, two USACERL breakthroughs appear imminent:

Basic Research in Nuclear Magnetic Resonance Imaging. Nuclear magnetic resonance (NMR) imaging has many potential field applications for the nondestructive evaluation of infrastructure components, but current technology is slow and bulky. USACERL research demonstrated that magnetic resonance imaging (MRI) equipment using quantum feedback control can work with a smaller magnet and take much quicker measurements. This USACERL innovation makes NMR technology feasible for diverse field applications—infrastructure inspection, mapping natural resources, and medical imaging of battlefield casualties. Feedback control applied to a related technology—nuclear quadrupole resonance (NQR)—can detect nitrogen compounds to locate explosives, and can also detect calcium isotopes for use as a security tool (to detect people) or to locate archaeological sites on Army lands.

> *This technology is only the second proven application of quantum control theory in the world, and the first such application developed in the United States.*

Basic Research in Spatial Databases. USACERL and a consortium of Federal agencies, research universities, and industrial partners have begun developing computer code that will enable GIS users worldwide to access heterogeneous and mutually incompatible electronic geodatabases through a public-domain software environment. The Open Geodata Interoperability Specification (OGIS) project, launched in June 1993 and

funded by USACERL this year, will produce and implement a software environment enabling users to access and use geodata at remote locations, regardless of the original model structure or data file format.

The development of OGIS is a response to the Administration's recognition that public access to geodata is essential, and that application technologies must be developed to facilitate the distribution of spatial data within the components of the National Information Infrastructure.

When fully refined, this breakthrough will mitigate the $50 billion-per-year waste that the Office of Management and Budget (OMB) has attributed to the inability to share spatial data.

Leveraging of Industry, Academia, and Other Services or Agencies

Partnering With the University of Illinois

A comprehensive partnership with the University of Illinois at Urbana-Champaign (UIUC), one of the nation's top research universities, was built into USACERL's mission as the Army conceived the organization in 1966. The concept was to create a mutually beneficial arrangement that would give the Army access to the personnel, resources, equipment, and facilities of an elite research university while providing value-added as a noncost asset of the university. The benefits of this partnership to the Army and DOD have proven far more extensive than could have been anticipated in the 1960s.

USACERL works with Army and DOD customers to identify problems or user requirements. USACERL then guides UIUC in identifying construction engineering R&D priorities for the Army's University Research Initiative (see "Leadership in Joint, Multi-Service, and DOD-Wide Programs" later in this chapter). UIUC provides R&D depth—internationally renowned researchers and cutting-edge facilities—not otherwise available to the Army in-house. A central aspect of the partnership is USACERL's involvement in UIUC's Advanced Construction Technology Center. Research conducted under the center forms the basis for part of the exploratory development performed by USACERL.

The university is also landlord for USACERL, and USACERL is an Allied Agency of UIUC—the only Army laboratory so designated. The following is a partial list of advanced equipment and facilities to which USACERL has open access as an Allied Agency. An asterisk (*) denotes a UIUC National Research Center:

- National Center for Supercomputing Applications*
- The Beckman Institute
- Coordinated Science Laboratory*
- Knowledge-Based Engineering Systems Research Laboratory*
- Composite Materials Center*
- Hazardous and Toxic Waste Laboratory
- Environmental Water Quality Laboratory
- Semiconductor Fabrication System
- Air Conditioning and Refrigeration Center*
- Plasma Energy Research Laboratory
- Bioengineering Research Laboratory*
- Wave Propagation Laboratory.

USACERL and UIUC also operate more than a dozen joint research programs and centers. A partial list follows; an asterisk denotes facilities onsite at USACERL:

- Acoustics Laboratory*
- Construction Robotics Center*
- Ion-Plating Laboratory*
- Midwest Seismic Consortium Laboratory*
- GIS Laboratory
- Plasma Arc Laboratory.

The USACERL Resource Management Office estimates that this arrangement gives the Army access to $150 – $200 million worth of UIUC resources.

In FY93, USACERL employed more than 460 UIUC graduate students through competitively awarded research contracts, and 106 faculty and staff through Intergovernmental Personnel Assignment contracts. At the same time, 26 USACERL researchers held seats as UIUC adjunct professors. Interdisciplinary cross-fertilization of ideas and expertise is inherent in this partnership. Through it, the Army takes advantage of not only UIUC's engineering disciplines, but also forestry, architecture, computer engineering, library science, economics, law, archaeology, medicine, environmental studies, and many others.

Partnering Programs and Mechanisms. Collaborative efforts extend to other top research universities, all three Services, nonmilitary government agencies at all levels, top industrial enterprises, and innovative small businesses. These partnerships are executed through the USACE Construction Productivity Advanced Research (CPAR) program, the Federal Small Business Innovative Research (SBIR) program, and other Cooperative Research and Development Agreements (CRDAs), Memorandums of Understanding (MOUs), and Interagency Agreements (IAs).

CPAR projects are executed through CRDAs. Over the past 5 years, private-sector investment in CPAR has risen by a factor of 6.4, considerably faster than the rise in the Corps investment (a factor of 4.3). The ratio of industry investment in CPAR to Corps investment was 1.6 to 1 in FY93.

In FY93, USACERL had 32 active CRDAs—mostly through CPAR—with 3 more pending. The most recent are highlighted in **Table 1.**

USACERL's SBIR program has grown by a factor of 5 in the past 5 years. In FY92 USACERL began to leverage this Federal set-aside money with investment from other government agencies—notably, the Federal Highway Administration—interested in the R&D being conducted. SBIR success stories from FY93 include the Underground Storage Tank Detection System (in partnership with Geophex, Ltd.) and VecLiner, a labor-saving system for digitizing contour maps in CAD terrain models (in partnership with VectorVision Corp.).

In FY93, USACERL had 34 active MOUs and 19 IAs. Most were with Federal agencies (25),Army elements (10), and USACE organizations (9). Others were with other military Services, state governments, universities, and private industry.

Spin-Ons

Biodiversity Research MOU. USACERL researchers are preparing an MOU between DOD and the Biodiversity Research Consortium (comprising the U.S. Departments of the Interior and Agriculture, The Nature Conservancy, and USEPA). DOD's participation will bring together scientists and engineers from the Corps laboratories, R&D components of the other Services, the Major Range and Test Facility Bases Environmental Coordinating Committee, and DOD's Legacy Biodiversity Task Area. DOD's involvement is based on the need to balance cooperative biodiversity management against the potential disruption of the military mission.

Plasma Arc Center for Hazardous and Toxic Waste Mitigation. During FY93 USACERL and the Georgia Institute of Technology codeveloped an asbestos destruction program using Georgia Tech's experimental plasma arc furnace to vitrify asbestos fibers into a nonhazardous, chemically inert material. This technology will reduce the Federal government's multimillion dollar cost of removing and disposing of asbestos from approximately 192,000 public buildings in the United States. USACERL applications of this experimental technology may include gasification, vitrification, and environmentally safe destruction of a wide range of toxic and hazardous waste materials.

Advanced Collaborative Systems Laboratory (ACSL). The ACSL, a cooperative effort of USACERL, UIUC's Beckman Institute, and other UIUC departments, is a member of the Collaborative Systems Consortium—an association of industrial and academic partners conducting research in technologies supporting software engineering. Industry participants include Fujitsu, Sun, Bull, Hewlett-Packard, and Intel. USACERL's

Table 1. Recent USACERL CRDAs.

R&D Partners	Technology	Date
INTERGRAPH Corporation	MicroStation Mentor	4/8/91
NFE, L.P.	Productivity Risk-Analysis Tool	10/21/91
Northwest Louisianna University	Low-Cost Personal Computer Based System for OSHA Compliance	2/27/90
Kenney/Williams/Williams	Buildings Assemblies Systems	6/21/90
University of Texas at Austin Constrsuction Industry Institute	Advanced Construction Technology System	7/12/90
Bechtel Group, Inc.	HVAC Simulation and Balancing Tool	8/24/90
The International Masonry Institute	Mechatronically Assisted Masons Aide	10/23/90
Georgia Tech University	Destruction of Asbestos Using Plasma Arc Technology	11/21/90
University of Nebraska	High Performance Ultra-Light Concrete Masonry Unit (CMU)	3/5/91
Nebraska Technology Development Corporation	Prestressed Clay Brick Walls	3/5/91
Robert Silman & Associates	Nondestructive Testing Techniques	3/5/92
Rutgers University	Developing Construction Materials from Commingled Waste Products	5/12/92
Research Foundation of SUNY	Automated Thermal Spray Technology	5/29/92
Alaska Department of Transportation	Biomediation of Hydrocarbon Contaiminated Soils and Groundwater	5/30/92
EBASCO Services, Inc.	Robotic Inspection System for Buried and Submerged Structures	4/9/93
South Dakota School of Mines & Technology	Demonstration of Advanced Composite Cables for Use as Prestressing in Concrete Waterfront Structures	4/12/93
West Virginia University Research Corporation	Full-Scale Concrete Bridge Deck Reinforced with Fiber Reinforced Plastic	5/9/93
State University of New York (SUNY)	Hi-Molecular Weight and Recycled Polymer Blends for Thermal Spray Coating	7/6/93

work targets the development of integrated systems language environments to enable DOD to produce integrated, collaborative software systems to support Army combat simulations and modeling. This work directly addresses the goals of the Army Model Improvement Program (AMIP) requirements (section 3.b.(1): R1-R6) and its Army Model Hierarchy (AMH).

Technology has been spun-on via research models, shared facilities, and the professional involvement of three USACERL principal investigators PIs and 17 graduate students. USACERL's work has contributed to eight master's degree theses, two doctoral dissertations, three papers in refereed journals, and sixteen presentations at conferences. Four software programs developed by UIUC with USACERL support are now available for Army use: Conversation Builder (release 2.9), a computer-supported collaborative work environment; CASTLE, a protocol for collaborative software development; Scrutiny, a review/inspection tool; QAP, a bug-tracking tool; Automatic Programming for Unix; Analogical Reasoning Engine; and CLOS, an ObjectStore interface for Palette.

Unmanned Aerial Vehicle Research. In collaboration with the Navy Unmanned Aerial Vehicle Joint Program Office and UIUC robotics experts, USACERL is creating new Army installation environmental applications for the Navy's small drone aircraft, which was used for battlefield surveillance in Operation Desert Shield/Desert Storm. Potential applications include land-condition surveys and monitoring threatened and endangered species.

Robotics Technology Center. This center was established in FY93 by USACERL and UIUC to spin-on robotics technologies to help Army installations manage their infrastructure and environment. The Center includes Georgia Tech, the International Masonry Institute, Naval Sea Systems Command, and the Navy Unmanned Aerial Vehicle Joint Program Office.

Concurrent Engineering Center. This center is a collaboration with UIUC, Carnegie Mellon University, the Massachusetts Institute of Technology, and Stanford University to develop an Agent Collaborative Language (ACL) to allow interaction between agent-based design tools used in USACERL's Designer Software (discussed earlier under Goal 4, "Investment for Quality Facilities." Each university will develop its own interface, after which the language will be tested on a COE design project. The ACL will be proposed as a standard to the National Institute of Science and Technology.

Wisconsin Procurement Institute. The Wisconsin Procurement Institute (WPI), a nonprofit organization that helps Wisconsin companies compete for Federal contracts, worked through USACERL to gain access to the Corps' Facilities Engineering Applications Program (FEAP). Through FEAP, WPI will demonstrate candidate technologies that address Army facility R&D needs. USACERL will use this "smart buyer" approach with WPI in FY94 to demonstrate at Fort Jackson an innovative electro-pulse shield for protecting rebar in concrete block basements against moisture. Spinning-on technologies screened by WPI can potentially save the Army millions of dollars on exploratory development while promoting inbound technology transfer from the private sector.

Spin-Offs

Renewables and Energy Efficiency Planning (REEP). In FY93 USACERL researchers began expanding the scope of REEP's analytical capabilities to include Air Force and Navy facilities; a DOD-wide model is scheduled for release in February 1994. REEP is fully described earlier in this chapter under Goal 4, "Investment for Quality Facilities."

Open GIS Foundation. USACERL formalized its geographic information system (GIS) partnering efforts under a Cooperative Research and Development Agreement (CRDA) between USACERL and an umbrella agency called OGF, the Open GIS Foundation. OGF is a not-for-profit agency supporting the community of GRASS users worldwide. Through OGF, the Army will hand off GRASS GIS developments to commercial, academic, and government enterprises. In return, the Army will receive software enhancements and support via technology, newsletters, and conferences sponsored by OGF. The CRDA addresses Vice President Gore's recommendation to create market dynamics (*Creating a Government That Works Better and Costs Less*, p 60) and "subject public organizations to market dynamics, stimulate the creation of private enterprises, or spin off public enterprises to the private sector." OGF sponsoring organizations include DBA Systems, Data General Corporation, Dell Computer Corporation, Intergraph Corporation, Sun Microsystems Computer Corporation, EUROGIS, Rutgers University, the University of Arkansas, the University of California at Berkeley, and UIUC.

OGIS Project. Participants in this project, discussed previously under "Breakthroughs," include the USDA Soil Conservation Service, the Massachusetts Institute of Technology, the Intergraph Corporation, Sun Microsystems, the University of California at Berkeley, Logiciels et Applications Scientifiques Incorporated, the Open GIS Foundation, and others.

GRASS Technology Transfer. Seven researchers in USACERL's Environmental Laboratory shared a Federal Laboratory Consortium (FLC) Award for Excellence in Technology Transfer for developing support structure

USACERL's Theater Construction Management System, which was hot-tested in Desert Shield/Desert Storm, was one of almost 20 USACERL products transitioned in FY93.

and mechanisms to transfer GRASS technology to the public and private sectors. In his letter of congratulations to the recipients, Secretary of Defense Les Aspin wrote that "technology transfer is an important part of this Administration's plans to help revitalize the American economy," and reiterated the importance of "realizing the potential for private sector uses of the technologies developed in our military laboratories." The GRASS team was cited for its development of software source code and documentation, public-domain access via an Internet file transfer protocol server (456 copies transferred), and its electronic bulletin board forums for users (479 subscribers, over 3200 messages) and programmers (246 subscribers, over 550 messages).

Urban School Renewal. Through work with UIUC's Urban School Improvement Project (USIP), USACERL spun off GRASS technology to help school administrators, city officials, social agencies, healthcare providers, and law enforcement officials address education problems in distressed urban areas. Raw academic, law enforcement, and demographic data are exported to GRASS to create maps to illustrate problems and develop remediation strategies. During FY93, USIP used GRASS to help Chicago's DuSable High School reorganize, collect academic data, allocate resources, plan programs and staff development, analyze problems, and improve multiagency programming. The USIP office plans to spin off this GRASS application as a commercial product by the end of FY94.

USACERL's spin-off of GRASS for urban school improvement applications has attracted the attention of other public agencies and private industry. In FY93, the U.S. Geological Survey, the Federal Bureau of Investigation, the National Aeronautics and Space Administration, Autodesk, Inc., and Dell Computers joined the USIP advisory board.

Joint, Multiservice, and DOD-Wide Programs

University Research Initiative. USACERL's leadership in the Army's University Research Initiative has repeatedly been acknowledged both by USACE and at the DA level. In a 15 July 1992 memorandu[illegible]ERD-ZA cited USACERL's "unique interaction w[illegible] University of Illinois" as a model for relationship[illegible]ween Army laboratories and research universities. In a 25 February 1993 memo, SARD-ZT recommended that all Army laboratories emulate "the successful CERL/University of Illinois model." (See"Leveraging of Industry, Academia, and Other Services or Agencies.")

Lead Agency for STOs. USACERL is the lead agency for two new Army STOs:

- Environmental Compliance (STO VI.C.12)
- Environmental Conservation (STO VI.C.13)

Accomplishments under these two STOs were discussed previously under "Meeting Assigned Objectives."

Lead Agency for Tri-Services Reliance. USACERL was designated the lead agency for six Project Reliance Civil Engineering Sub-subareas and six Environmental Quality Sub-subareas. In the two lists below, a single asterisk (*) denotes USACERL as DOD's only in-house science/technology capability. A double asterisk (**) means USACERL is DOD's sole science/technology capability. Under Civil Engineering, USACERL is the lead for:

- Construction/Acquisition* (Conventional Facilities)
- Installation Operations* (Conventional Facilities)
- Maintenance and Repair* (Conventional Facilities)
- Energy and Utilities* (Conventional Facilities)
- EMP/TEMPEST Hardening (Survivability and Protective Structures)
- Theater Construction Management* (Sustainment Engineering)

(Note that the Conventional Facilities sub-subarea has since been consolidated into two: Infrastructure Acquisition and Installation Management and Public Works.)

In support of Environmental Quality, USACERL is the lead for:

- Impulse Noise** (Noise)
- Training Area Management and Protection* (Base Support Operation)

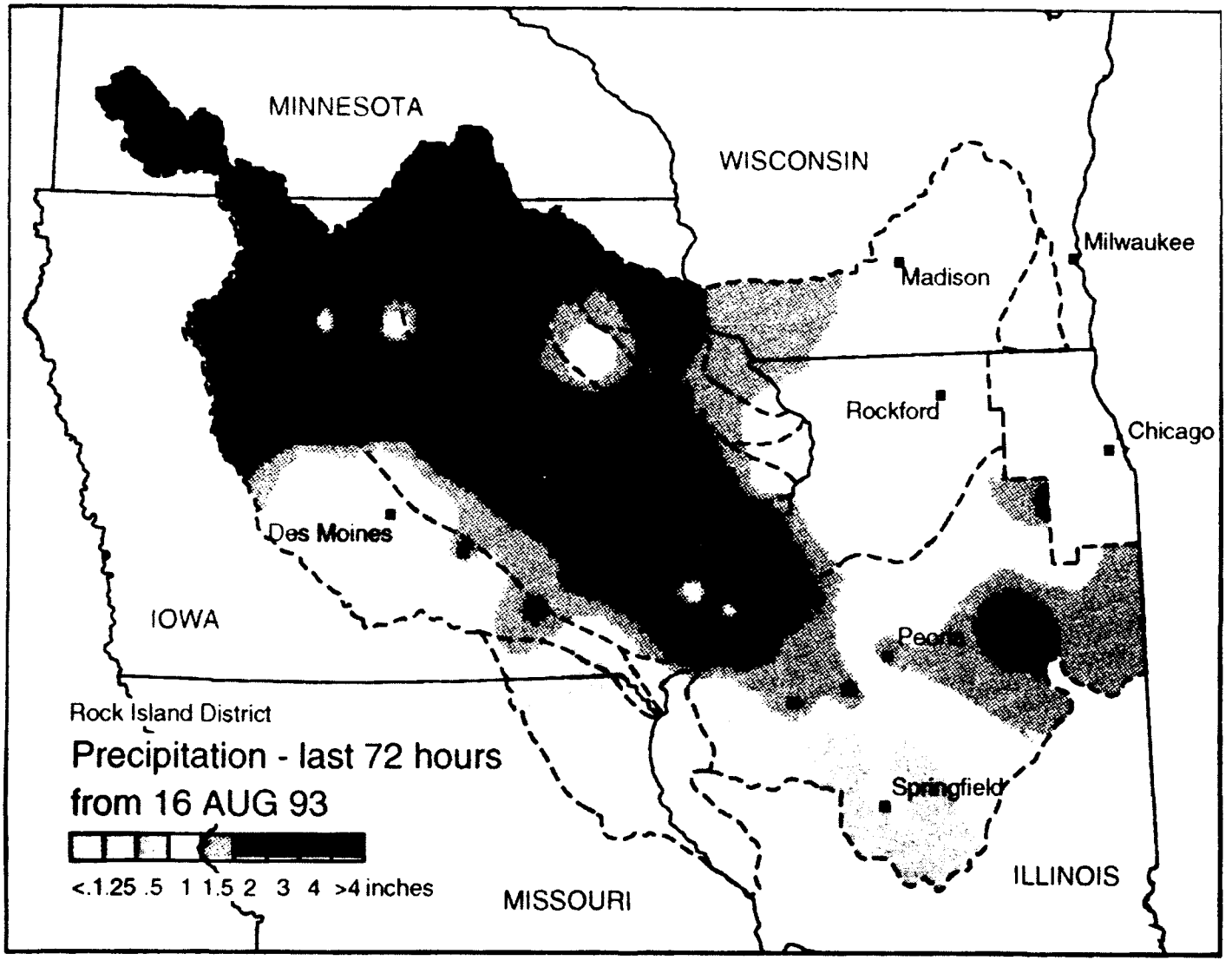
- Threatened and Endangered Species* (Base Support Operation)
- Installation Operations* (Base Support Operation)
- Explosives Manufacturing and Demilitarization* (Base Support Operation)
- Ground Equipment Systems* (Base Support Operation).

During FY93 a USACERL Laboratory Chief chaired the Tri-Services Reliance Environmental Quality Strategic Planning Panel, and USACERL researchers chaired two pillars—Compliance and Conservation.

Interagency LBP Research. USACERL is the primary agency funded by the DOD Interagency Lead-Based Paint Task Force to research lead-based paint, identify problem structures, and develop new methods to handle lead problems. A USACERL researcher co-chairs this task force, comprised of representatives from the three military Services, the Coast Guard, the Defense Logistics Agency, USEPA, the Department of Housing and Urban Development, and the Centers for Disease Control and Prevention.

Quick Fixes for Troops

Flood Relief Assistance to Rock Island District. USACERL responded to USACE Rock Island District to help alleviate the devastation caused by the 1993 Mississippi flood. Personnel coordinated, loaned, transported, and installed computer hardware and software at Rock Island District, enabling them to more quickly and reliably ascertain flood patterns. Paper maps were converted into electronic data. The USACERL team wrote a GRASS program to automatically create maps of precipitation and resulting flood patterns, depicting



This precipitation map was generated by GRASS to help Rock Island personnel anticipate flooding patterns in their stricken district.

trends over the previous 6, 12, 24, 48, or 72 hours. The maps were producible with one command line, enabling Rock Island personnel without GIS experience to take advantage of the GRASS software.

Flood Assistance to Taxpayers. Also in response to the 1993 Mississippi flood, USACERL set up an emergency operations center as a local information clearinghouse for USACE flood-related emergency actions. Fifteen USACERL technical teams (comprising 96 engineers and scientists) were organized for immediate response to communities, and 85 other employees volunteered for support activities. Flood-site work included reservoir inspection, flood mapping and prediction, levee reinforcement, and consultation on drinking water supplies. USACERL expertise was also used in consultations on post-flood recovery, including inspection of buildings, bridges, and pavements. USACERL activities aided at least 10 flood-stricken communities. Volunteer time exceeded 1,100 hours.

Field Assistance to Installations. In FY93, TAC implemented a program to more efficiently disseminate USACERL products and support to the field. On a reimbursable basis, TAC contractors trained Fort Lewis personnel to help other installations meet environmental compliance and conservation requirements using USACERL technologies. TAC leveraged Fort Lewis's aggressive environmental stewardship to create a source of expertise in the field where other installations can turn for the same kind of assistance. This concept enables new users to get their technical assistance directly from other users.

HBCU/MI and Other Outreach Programs

Indoor Air Quality Laboratory. In FY93, USACERL and the North Carolina Agricultural and Technical State University (NCA&TSU) investigated how to raise indoor air quality (IAQ) while lowering energy costs. NCA&TSU—a historically black university—has a state-of-the-art test chamber and recognized expertise in heating, ventilating, and air conditioning (HVAC) system design. This partnership supports ARO's Infrastructure Support Program for Historically Black Colleges and Universities and Minority Institutions (HBCUs/MIs). Resulting in part from this collaboration, NCA&TSU was also awarded a contract by USEPA to expand its IAQ and HVAC research. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) is also interested in supporting the work.

Other Contractual Achievements. In FY93, USACERL awarded $686,079 for academic R&D contracts to HBCUs/MIs, achieving 89 percent of its goal. (This total represents 106 percent of the SADBU goal.) The following summarizes USACERL's FY93 contractual achievements with HBCUs/MIs:

- a 3.4 percent increase in representation of minorities and women in major occupational categories
- 9 task orders with HBCUs/MIs
- 14 contracts awarded to five HBCU/MI institutions (Stevens Institute of Technology, Clark Atlanta University, Howard University, University of New Mexico, and North Carolina A&T State University); subcontractors working with these lead institutions include other HBCUs/MIs
- 4 indefinite delivery contracts totalling $8 million (Clark Atlanta, Florida International, Howard, and Stevens Institute of Technology)
- 2 IPAs from HBCUs; one from an MI (University of Texas at El Paso, predominantly Hispanic)
- 4 SFRCs from HBCUs/MIs.

Outreach Programs for Women, Minorities, and Youth. USACERL recruited at HBCUs/MIs for its 1993 Summer Research Opportunity Program, whose participants work with researchers during a summer before college or graduate school.

In FY93, the USACERL's Federal Women's Program initiated a mentoring committee, offered workshops for resume writing for career advancement, offered counseling and Prevention of Sexual Harrassment training, and coordinated the Women in Science and Engineering (WISE) awards and conference.

USACERL continued its Internship Science and Engineering Program (ISEP) for the third year, bringing eight local high school students to USACERL to work side-by-side with USACERL researchers or technical personnel. All high school students are eligible for ISEP, but outreach to minorities and females is emphasized. Also during FY93 USACERL worked with a local middle school (junior high) to plan and begin the Young Women in Science program, which will offer 8th grade women the opportunity to work with USACERL researchers or technical personnel. USACERL scientists and engineers also periodically teach classes at this same middle school as part of the Discover E(ngineering) program. A recent offering was six classes on photovoltaic science.

Also in the past year USACERL actively supported Parkland Community College's application for a National Science Foundation (NSF) grant that will give minority students work experience in science and engineering fields. Plans are also underway for working with Parkland on a similar NSF grant to support teacher training in science and engineering fields.

II Vision, Strategy, and Plan

Organization Vision, Strategy, and Plan

The *Government Performance and Results Act of 1993* (PL 103-62) requires all agencies to submit 5-year strategic plans to the Office of Management and Budget by the end of FY97. In FY93 USACERL was years ahead of that requirement, motivated by:

- steep increase in program in FY91
- Tri-Services Reliance
- internal reorganization
- distribution of mission between ACS(IM) and USACE
- projected decrease in DOD-allocated resources
- *Chief Financial Officers Act of 1990* (PL 101-576).

USACERL Vision

The vision was developed and adopted during the first half of FY93 in a process of all-way participation and communication at all levels of the organization. The USACERL vision is this:

> *We Will be the Recognized Leader for Infrastructure and Environmental Research, Development, and Support.*

The vision is a concise statement of how USACERL will help fulfill the Army vision of being a "total force trained and ready to fight, serving the nation at home and abroad; a strategic force capable of decisive victory." USACERL's vision links directly to the Army vision through the definition of "installations" given in *Installations—A Strategy for the 21st Century* (p 1):

> *Army installations are "...enduring and continuously improving communities of quality facilities... environmental stewards for present and future generations... world-class strategic power projection and sustainment bases for America's Army."*

The vision was crafted with input from all levels of the organization. An early version of a vision was drawn up by senior leaders in FY92 and publicized throughout the organization. Bottom-up feedback indicated that many employees saw weaknesses in the vision and did not feel ownership. Consequently, early in FY93, formulation of a vision was the topic of a 2-day senior leaders' retreat that included USACERL senior, middle, and junior managers, plus principal investigators, members of TQM process action teams, and the Quality Management Board. Alternative versions of the vision were composed and discussed, and a strawman version was agreed upon. Managers were assigned to present the draft vision for discussion to all R&D, technology transfer, and support work groups. Attendance at the meetings was required for all personnel. Input from all vision meetings was posted on the in-house electronic bulletin board and given to the Commander and Executive Steering Committee for followup. Seven internal organizations—including the laboratory level, R&D divisions, TAC, support offices, and administrative teams—subsequently developed their own visions to adapt the USACERL vision to their respective missions.

Innovative composite materials being developed jointly by USACERL, research universities, and industry partners are being investigated to replace steel rebar. Use of noncorroding materials for reinforcement will prevent the kind of concrete damage shown above.

The Communications PAT conducted two surveys to measure employee awareness of the vision. The first survey measured employee awareness of the original FY92 vision, and a followup survey measured awareness after the new vision was composed, discussed, promoted, and publicized via internal paper and electronic media. The first survey netted 279 responses, with 81 correct answers and 152 incorrect or "don't know" an-

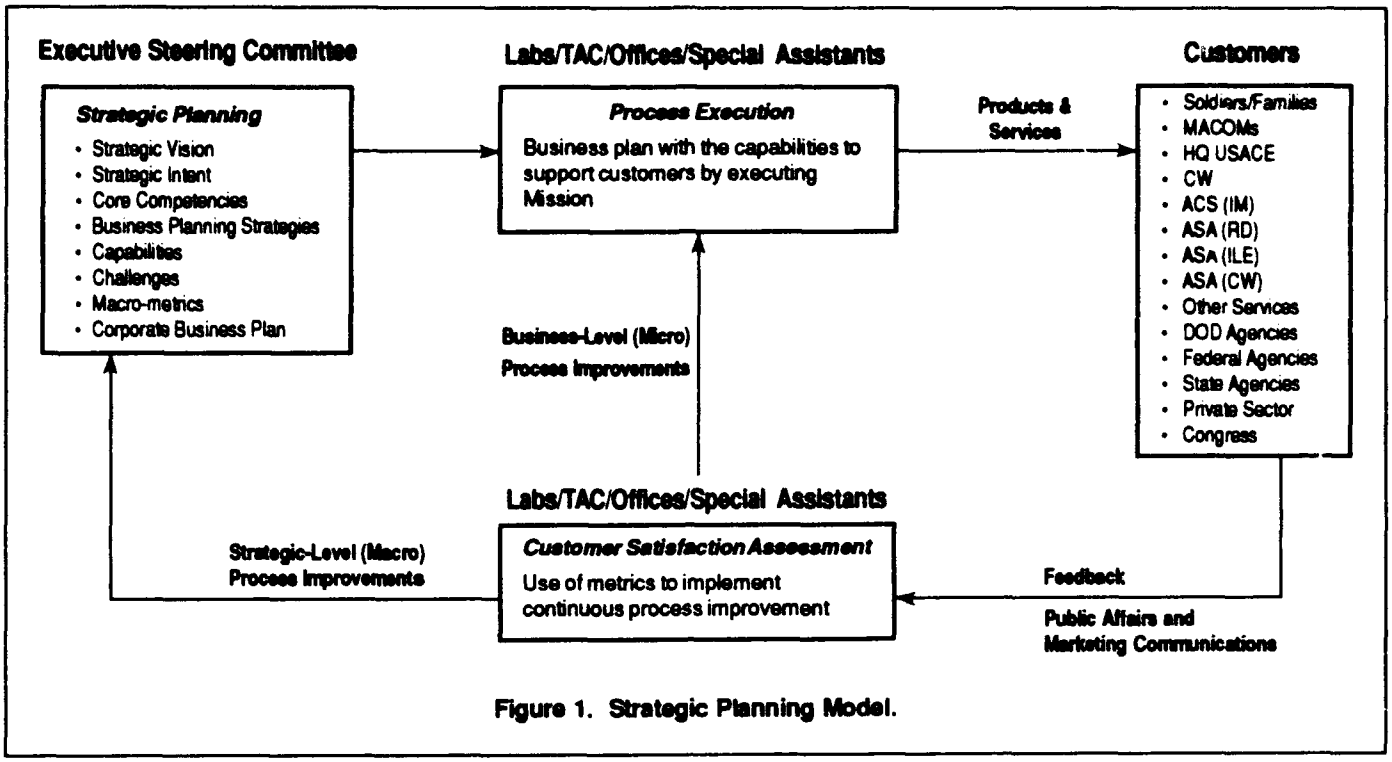


Figure 1. Strategic Planning Model.

swers. The followup survey drew 320 responses, with 255 correct answers and only 37 incorrect. Clearly, internal awareness of the vision climbed dramatically after the successful FY93 visioning process and followup.

Corporate Strategic Planning

Before FY91, USACERL conducted strategic planning on an *ad hoc* basis. Corporate strategic planning formally began in FY91 with the establishment of an Executive Steering Committee (comprising the Commander, Director, and senior managers) and development of CERL2000—USACERL's strategic plan for implementing TQM. A Strategic Planning Process Action Team (PAT), launched in the second year of CERL2000 implementation, recommended a set of strategic planning tools and processes. The Executive Steering Committee then used as a benchmark the draft Army Materiel Command (AMC) business planning process. USACERL was able to spin-on important elements of AMC's draft planning processes instead of "reinventing the wheel." The synthesis of these two FY93 efforts was a draft strategic planning process, which was briefed to USACE Deputy Chief of Engineers MG Sobke in December 1993.

Premise and Management Objectives. The premise of all the Strategic Planning PAT's recommendations was that *the strategic plan exists primarily for the advancement of all Army STOs and National Military Strategy goals that fall within USACERL's mission.*

The management objective for strategic planning is to create the strategic framework for short- and long-range business plans, driven by external customer needs, which will bring USACERL closer to fulfilling its strategic vision. (A secondary objective is to clearly define for staff where the organization is going so employees can fully participate in getting there.)

The Model. **Figure 1** shows the strategic planning model, which was adapted from the AMC model. The Executive Steering Committee creates the strategic framework (comprising core competencies, a strategic vision for each, goals, and strategies for attaining the goals) for business planning—execution of the USACERL mission through delivery of R&D products and technical assistance needed by the customer. Customer feedback on delivered products and services—and the process by which they were developed—is the chief input to USACERL's customer satisfaction assessment process. (The launch of a formal external customer satisfaction assessment process is scheduled for second quarter FY94.) The satisfaction assessment process feeds into both strategic- and business-level (i.e., macro and micro) process improvements, as shown. As part of a continuous cycle for accomplishing assigned STOs and strategic installation goals, strategic planning is both continuous and adaptive.

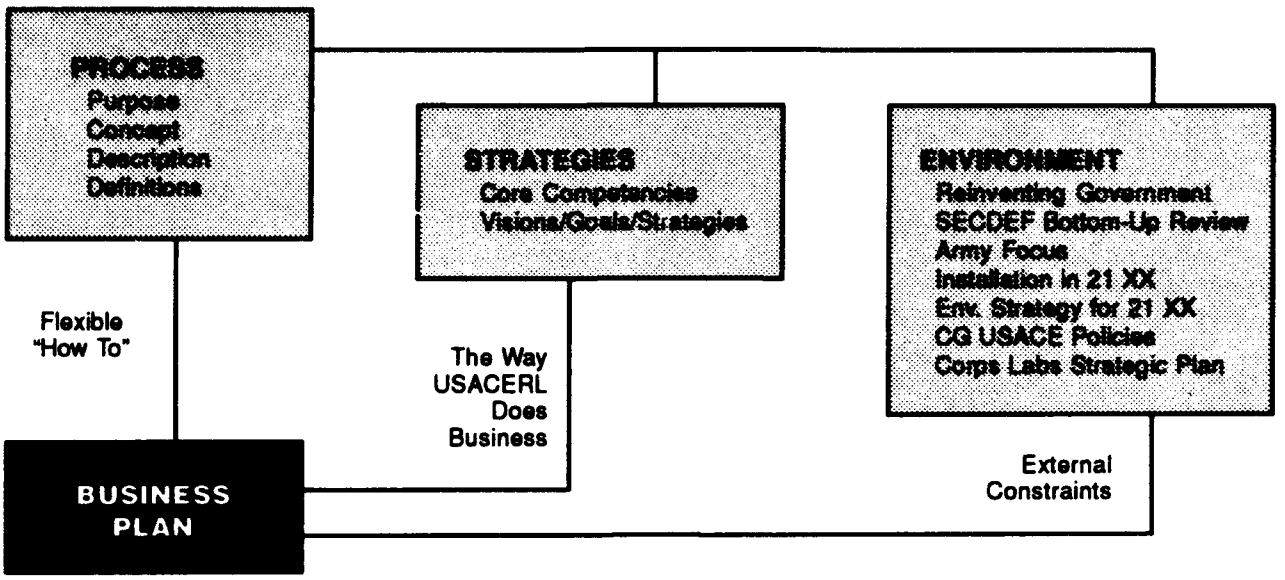


Figure 2. Business Plan Inputs.

Strategic Intent and Core Competencies. USACERL's strategic intent encompasses the following four areas:

- installation management and BASOPS in the Army
- environmental security in DOD
- CONOPS and Corps Reliance in Civil Works
- city management and engineering in the nation (through spin-off and technology transfer).

USACERL's capabilities for serving customers in all these four areas originate from six *core competencies*, which are capabilities that (1) make a significant contribution to the Army, (2) the absence of which would present unacceptable risk to mission accomplishment, and (3) are not available to the Army in USACE, ACS(IM), other government agencies, the private sector, or academia.

A strategic vision has been developed for each core competency. The six core competencies, and their strategic visions, are:

1. *Technology-based product development and technology transfer*—to equip and sustain the Army with innovative, affordable, rapidly fielded technologies to effectively support power projection platforms and training installations
2. *Technology-based customer problem diagnosis and technology transfer*—to equip and sustain the customer with innovative technologies to comprehensively diagnose environmental and infrastructure problems for rapid, resource-effective solutions
3. *Technology-based sustainment-engineered problem diagnosis and technology transfer*—to equip and sustain the customer with innovative technologies that seamlessly integrate installation operations with environmental stewardship requirements
4. *Leveraging and partnering excellence*—to enhance customer support by leveraging Army resources with elite research universities, private industry, government agencies, and international communities
5. *Strategic support excellence*—to provide Army customers with rapid, responsive, and affordable support capabilities
6. *Common strategic elements*—to strategically employ USACERL resources and capabilities (work force, process reengineering, TQM culture, information management, resource management, facilities, etc.) in support of the organization's strategy.

Plans and Programs Flowing From Strategy

USACERL's draft business planning process was finished this year, and completion of the business plan itself is scheduled for the third quarter of FY94.

Figure 2 shows inputs to the USACERL business plan, adapted from the AMC draft planning process. The "how to" elements of the planning process feed directly into the plan. Other aspects feed into the business-level strategies for each core competency, affecting the way the organization does business. The planning process is also affected by external constraints that are part of the

greater environment in which USACERL operates. Organizational roles in business planning are as follows:

- the Executive Steering Committee provides vision-driven guidance and a forum for discussion
- the Plans and Programs Officer institutionalizes the planning process, measures progress, addresses barriers to business planning, and codevelops and maintains the plan with senior managers
- "core competency advocates" provide strategic guidance and facilitate integration of the core competencies into the plan.

Incentives Linked to Vision and Strategy

CERL Regulation (CR) 690-7. This regulation, *Dossier for Grade Evaluation*, includes in paragraph 3.c an evaluative criterion for paneling (Factor IV review) that requires the researcher to fully document products and services fielded during that researcher's tenure at USACERL. Some of the researcher's requirements for upgrade or performance awards are to document the product's users, extent of use, benefits provided, and other aspects that indicate how successfully the product fulfills an Army need.

Total Army Personnel Evaluation System (TAPES). TAPES was implemented at USACERL in the first quarter of FY94. The Director's performance objectives, mutually developed and agreed upon with the USACE Director of Research and Development, include the following:

- Lead development of the USACERL corporate strategic plan focused on core competencies to support the USACE, ACS(IM), SARD, DUSD-ES strategic visions (30 April 1994), and lead coordination with DRD strategic plan (30 July 1994).
- Lead development and coordination of the USACERL business plan focused on technologies to provide products and services to assist customers meet their operational and strategic targets in 21XX (30 September 1994).
- Oversee planning and execution of USACERL RDTE, Civil Works, customer support, and technical assistance programs to meet needs, milestones, and budgets estab-

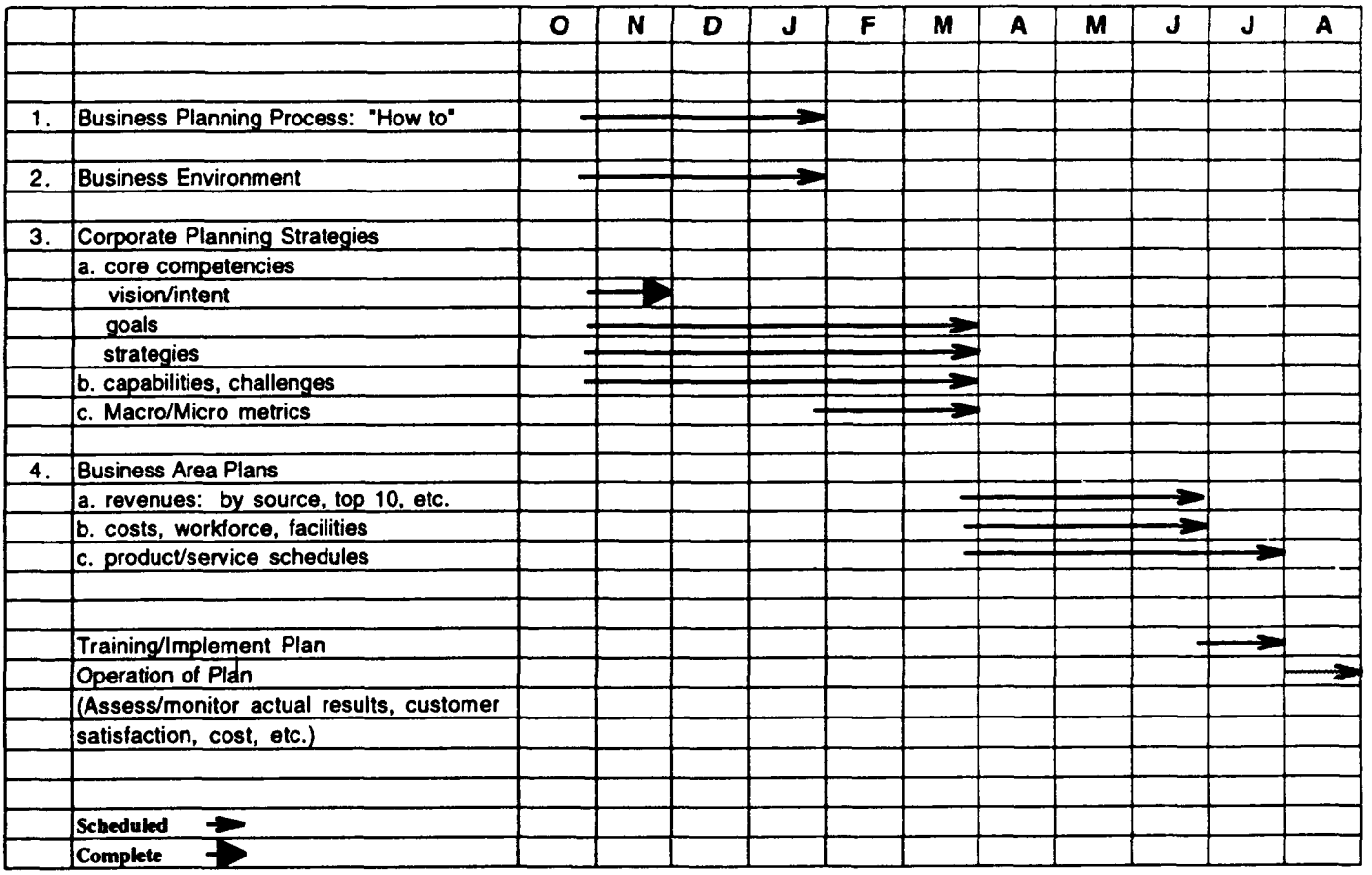


Figure 3. USACERL Business Plan Implementation Schedule.

lished in partnership with customers, with emphasis on increased partnering with customers, the private sector, academia, and other government agencies.

USACERL senior managers compose their annual objectives cooperatively with the Director in direct support of his objectives. Actions required to enable fulfillment of the Director's objectives cascade to the appropriate level of the organization. Through this accountability mechanism, individual performance awards and quality step increases are linked directly to USACERL's vision and strategy.

Three other incentive awards, discussed in Chapter IV under "Accountability and Personnel Linked to Process," are being planned or are ready for implementation. These awards will recognize individuals and groups for Total Quality (TQ) and process improvements. The awards in effect acknowledge TQ as the cement linking employee performance to USACERL's vision, and provide employee incentives outside the TAPES process.

Plan Implementation and Measurement

Implementation Schedule. **Figure 3** shows the implementation target dates for USACERL's business plan. The vision and intent for each core competency have been drafted. The how-to aspect of the planning process and analysis of the business environment are nearing completion, and all corporate planning strategies and metrics are scheduled for completion by the second quarter of FY94. Training and plan implementation are targeted for June 1994.

Metrics. The common denominator for all metrics will be USACERL's R&D output: practical, affordable, timely, mission-enhancing sustainable products and services (PATMESPS). The USACERL Business Planning Task Group is considering a core set of organizational success metrics for inclusion in the business plan. The two basic categories of metrics under consideration are (1) adoption and use of USACERL PATMESPS and (2) customer satisfaction. Under adoption, the metrics proposed are:

- Return-on-investment (ROI). An ROI study will be conducted for all PATMESPS. USACERL has conducted hundreds of ROI studies, but they have not previously been mandatory. The unit of measure will be the ratio of Army savings (or documentable cost avoidance) to total cost of product R&D.
- Degree of implementation. One unit of measure will be the number (or percentage) of targeted *users who have voluntarily implemented the product* for continuous use.

USACERL transitioned the LCTA component of ITAM in FY93.

Another unit of measure will be the number (or percentage) of USACERL PATMESPS *adopted by the Corps or Army for standard use*.

Under customer satisfaction, the proposed metrics are:

- number of site visits by managers
- number of phone checks routed to management by researcher
- in-progress reviews (IPRs)
- written yes-no satisfaction survey
- improvement over time (qualitative).

These metrics are discussed in more detail in Chapter IV under "Customer Satisfaction Metrics." As shown in Figure 3, development of the metrics is scheduled for completion in the second quarter of FY94.

III Resource Input

Professional Recognition

Patents, Papers, Citations, and Other Achievements

Patents. USACERL scientists and engineers have registered *28 patents* since 1970, and *24 more are currently pending* with the U.S. Patent Office. USACERL has three patent license agreements with industry, including the first one in USACE.

Papers and Presentations. During FY93, USACERL scientists and engineers published *25 papers in refereed journals.* They published *32 articles in other journals, trade papers, and industry publications* (not including inhouse military publications). During the same period, researchers had *98 symposium presentations or papers published* in symposium or conference proceedings. Listings in the *Citations Index* are shown in Table 2.

Major 1993 Awards and Recognition

- The 1993 *Dr. Wilbur B. Payne Memorial Award for Excellence in Analysis* for the best group analysis, to three researchers from USACERL's Energy and Utility Systems Division, for REEP
- The 1992 *USEPA Administrator's Award* to USACERL's Environmental Compliance Modeling and Systems Division, in recognition of R&D excellence and significant contributions to environmental improvement through pollution prevention
- The 1993 *Federal Laboratory Consortium Award for Excellence in Technology Transfer* to seven researchers from the USACERL Environmental Sustainment Laboratory, for technology transfer of GRASS
- *U.S. Army Corps of Engineers Safety Award of Excellence for 1992* for exceptional performance in safety and occupational health program management (4th award)
- *Honorable Mention, 1992-93 Army Communities of Excellence Awards (Special-Category).*

Historical awards and recognition include Army RDA Awards to 50 researchers, including the only Army scientist/engineer to have won three. Four researchers have been Army Engineer of the Year, and two have been named Federal Engineer of the Year. One has received the Women in Science and Engineering (WISE) Award.

Society Memberships

USACERL researchers accounted for more than 250 memberships in 105 professional societies, including:

- Air and Waste Management Association (5)
- American Anthropological Association (15)
- American Society of Civil Engineers (15)
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (21)
- American Society for Testing and Materials (6)
- Institute of Electrical and Electronics Engineers (13)
- National Research Council (3)

Table 2. Citations Index Listings.

Article	Author(s)	Journal	Date	No. Cites
Field Bioassessments for Selecting Test Systems To Evaluate Military Training Lands in Tallgrass Prairie	E. Novak	*Environmental Management*	1990	***38***
Correlations Between Validation and Definitive Study Results for Genotoxic Compounds	D. Shaeffer	*Regulatory Toxicology and Pharmacology*	1988	***27***
Wall Shear-Stress Measurements in Vertical Air-Water Annular 2-Phase Flow	G. Hewitt	*International Journal of Multiphase Flow*	1989	***23***
Indoor Firing Range Air Quality—Results of a Facility Design Survey	D. Schaeffer E. Novak	*American Industrial Hygiene Association Journal*	1990	***21***
Absorbing Boundary-Conditions for a Spherical Monopole in a Set of 2-Dimensional Acoustics Equations	R. Raspet	*Journal of the Acoustical Society of America*	1990	***19***
Nonpoint Source Pollution Modeling Using Models Integrated With Geographic Information Systems	C. Rewarts	*Water Science and Technology*	1993	***16***
A Knowledge-Based Approach to Support the Generation of Construction Schedules	D. Echeverry	*Computers and Structures*	1991	***9***

- National Society for Corrosion Engineers (4)
- National Trust for Historic Preservaton (7)
- Society for American Anthropology (14)
- Society of American Military Engineers (8)
- Society for Historical Archeology (6)
- The Wildlife Society (3).

Educational Profile

USACERL continues to offer quality educational opportunities to empower CERLites to help themselves by providing avenues for life-long learning. The Continuing Education Office sponsored a series of eight workshops on microcomputing that USACERL administrative staff identified as essential to better customer service (i.e., MS-DOS, spreadsheets, presentation graphics, etc.) CERLites attended other workshops on resume writing and using audiovisual equipment.

The USACERL-developed Principal Investigator Training course remains a foundation for the training and development of the laboratories' core research community. The intensive 40-hour course requires major effort from the 40 USACERL instructors.

Every permanent employee at USACERL may take tuition-free courses at the University of Illinois and mission-essential courses at four other area colleges. Each year one research support employee is awarded a semester of full-time study. This award has been given 11 times since 1985, and 80 percent of the recipients have been female or minority.

A year of advanced study also is awarded annually to a USACERL researcher for a full academic year at the University of Illinois. Since 1972, 21 researchers have benefited from this award—45 percent of them females.

Professional Development

Executive Development. Because of USACERL's 1991 reorganization, a major management training thrust continued in FY93. USACERL began focusing on senior management training even before it became an item in the Command Management Review, and saved over $100,000 in individual training costs by bringing many supervisory and technical courses inhouse. USACERL fully supports TDY assignments of managers and executive-track personnel to HQUSACE, HQDA, and DOD. These details provide participants the opportunity to observe, understand, and participate in the interactions between the components of DOD, specifically for program development, justification, and defense of the Corps of Engineers laboratories R&D programs. In FY93, USACERL executives were detailed to DRD [4], ASA(IL&E) [3], SARDA [3], MISMA [1], and DASA-IH [2].

Table 3. University Degrees.

	1987	1988	1989	1990	1991	1992	1993
PhD	32	37	42	43	40	44	*48*
MS	83	95	79	96	109	98	*107*
BS	42	49	49	54	78	79	*85*
Total	157	181	170	193	227	221	*240*

Note: 26 USACERL researchers are adjunct professors at UIUC.

Table 4. Employee Training Statistics.

	FY90*	FY92**	FY93***
Total hours training	6,274	11,447	*7,452*
Number of people trained	374	917	*446*
Number of courses attended	260	400	*446*
Average hours per trainee	20	35	*16.7*
Total Cost	$142,898	$193,502	*$239,906*

Notes: (*) denotes pre-TQM figures; (**) includes TQM startup training; (***) no longer includes inhouse training of less than 4 hours.

Continuing Education. USACERL professional development opportunities for scientists and engineers are listed below. The number of FY93 graduates of each program follows in parentheses:

- Personnel Management for Executives (5)
- OPM Executive Development Program (8)
- Harvard Senior Executive Fellows program (1)
- HQUSACE Mission-Related Graduate Program.
- Year of Advanced Study Award (1)
- DA Engineer and Scientists (Resources and Construction) Professional Development Program (1)
- Sabbatical Leave Program (through UIUC) (1).

State-of-the-Art Equipment and Facilities

USACERL's state-of-the-art facilities are summarized in Chapter 2 under "Partnering with the University of Illinois." Major computer assets onsite at USACERL include a Control Data 4330 (Environmental Sustainment Laboratory), a Sperry 5000/80 (Infrastructure Laboratory), a Sequent 2000/200 (Contracts), and a Control Data 4360 (Information Management). Almost 1,000 personal computers and desktop workstations are available onsite to USACERL scientist/engineers, technical, and support personnel:

- 8086 (4)
- 286 (80)
- 386 (310)
- 486 (393)
- Macintosh (44)
- Engineering workstations (150).

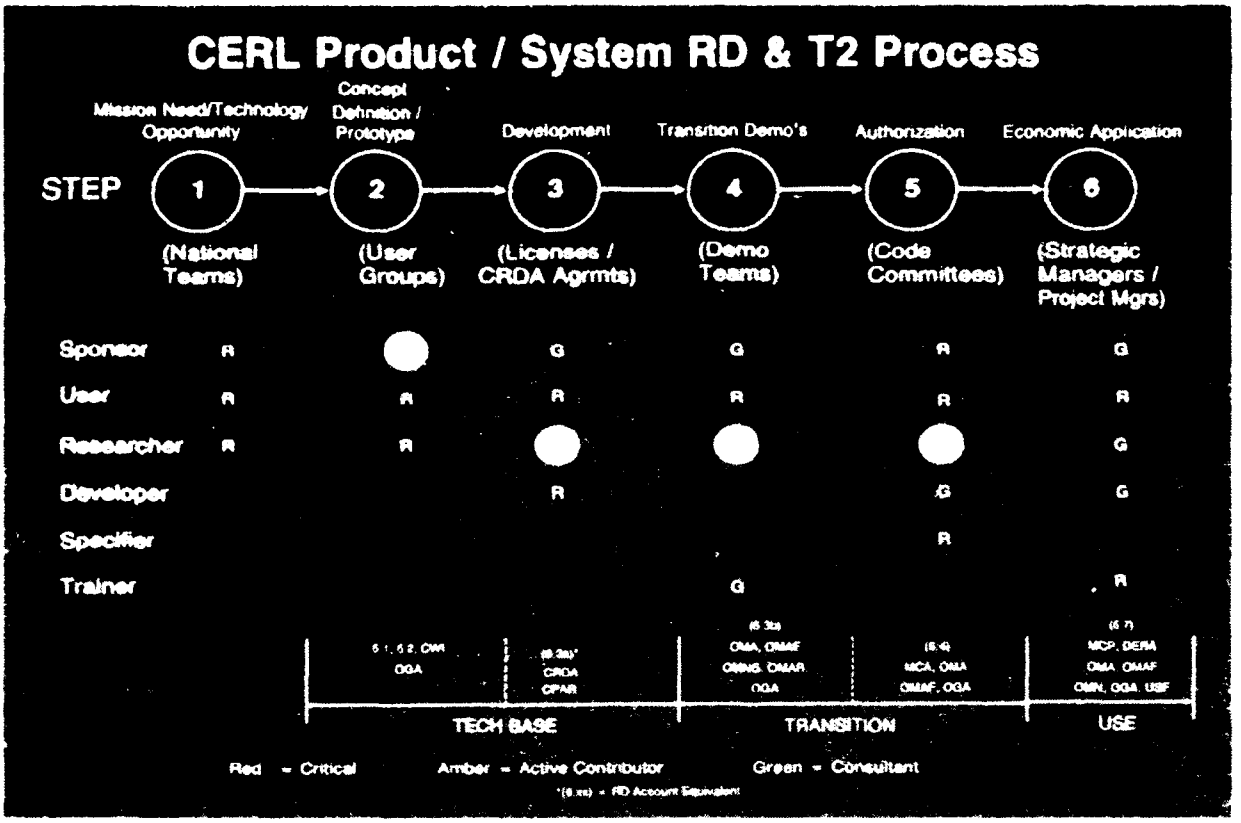


Figure 4. The Six-Step Process.

IV Continuous Improvement

The report on the National Performance Review recommended implementation and review of voluntary customer surveys to help managers of customer-driven programs quickly and easily evaluate the success of such programs. In Executive Order 12862, President Clinton directed Federal agencies to conduct customer satisfaction surveys and report on them by 8 March 1994. Publication of a customer service plan is required by 8 September 1994. USACERL is years ahead of this requirement.

Process

The Six-Step Technology Adoption Process. As shown in **Figure 4,** USACERL R&D and technology transfer is a six-step process. The cycle begins with the identification of an opportunity to meet an Army mission need with an innovative technology, and finishes with the economic application of the product or service. Of the six players in the process, the sponsor, end-user (customer), and USACERL researcher are involved in every step. As Figure 4 shows, *the customer's input is considered critical in all six steps.*

Customer-Driven Process Improvement. The formal foundation of USACERL's customer-driven process-improvement initiative is CERL2000, the strategic plan for implementing TQM. Customer input is the engine that drives continuous process improvement. All TQM initiatives—organization-wide training, surveys, PATs, focus groups, etc.—are based on the premise of customer-driven process improvement. The goal is permanent enculturation of customer focus at all organizational levels.

Formal Customer Satisfaction Surveys. In FY91 USACERL conducted its first formal survey of external customers with the aid of a private consulting firm, the Aslan Group. (An internal customer survey was conducted concurrently.) All PIs and team leaders were required to identify their most important customers, who were surveyed by telephone interviews and written questionnaires. The objective was to determine how satisfied USACERL's major customers were with the organization's people, processes, and products.

Low-frequency impulse noise from Army training ranges presents a major environmental compliance challenge. USACERL acoustics research helps preserve training capacity with minimal disturbance to neighboring communities.

The Aslan study found high customer satisfaction with USACERL people, but less satisfaction with how long it took to deliver products to the end user. Some customers indicated that USACERL PIs sometimes did not listen carefully to user needs, and overdeveloped products—'developed a limousine when a pickup truck would have sufficed.' The findings of the survey were considered only partially useful because little specific customer feedback was drawn out about the R&D processes themselves. (See "Customer Satisfaction Focus Group" below.)

Customer Feedback on Telephones. While the Aslan study was short on findings about the R&D process, it did unearth a very specific problem that needed rapid attention: customers perceived that it was often difficult to reach lab personnel or leave messages. USACERL responded by chartering one of its first process action teams (PAT)— the Telephone PAT. Through an internal survey, the team discovered much complexity to this seemingly simple problem: factors ranging from employee training, to phone ringer sound, to office layout. The PAT recommended:

- standard procedure for answering telephones and taking messages
- standard procedure for covering unattended phones
- training of all new employees in telephone procedures
- implementation of a state-of-the-market voice mail system.

Recommended procedures have been compiled into a draft CERL Regulation, and are scheduled for circulation, comment, and finalization during FY94. The voice mail system was procured during FY93 and went online in January 1994. Employee training on the system began at the same time.

Customer Satisfaction Focus Group. As noted above, the usefulness of the Aslan findings was limited. To address the problem, the Executive Steering Committee chartered a "PATlike" group called the USACERL Customer Satisfaction Focus Group. Among its other tasks, the focus group is considering which of several alternative survey methodologies and instruments to use in a followup customer satisfaction survey, scheduled for FY94. The followup survey will focus on customer satisfaction with USACERL's R&D and technology transfer processes. The survey's findings will feed into USACERL's strategic and business planning process, as described in Chapter II. The focus group will also recommend procedures for implementing ongoing customer satisfaction surveys as a formal tool for continuous process improvement.

Tiger Team. In FY93 USACERL initiated a swift and thorough response to a major dissatisfied customer, HQ FORSCOM. The customer expressed firm dissatisfaction about the lack of coordination between USACERL and HQ FORSCOM throughout research project execution, and was dissatisfied with the timeliness of project completion. FORSCOM representatives said this lack of coordination resulted in duplicative work, incompatibilities among certain R&D products, and unmet expectations. USACERL assembled a *Tiger Team*, comprising the Commander, senior management, and researchers involved with the customer. The Tiger Team went to HQ FORSCOM to meet with and listen to the

customer. The participants reached a consensus on the causes and effects of the problem. The Tiger Team then brought the customer's position back to USACERL management and principal investigators: response to FORSCOM was designated top priority. The Tiger Team brought the USACERL response back to the customer for discussion and approval. The results:

1. USACERL and HQ FORSCOM jointly redesigned their reimbursable proposal process to ensure that mutually agreeable expectations are established from the start
2. USACERL and HQ FORSCOM will meet annually to ensure that the partnership is working effectively.

The Tiger Team clearly succeeded in its effort: the FORSCOM Engineer said that the new agreements benefit FORSCOM in an improved partnership with USACERL ((FCEN-RDM) 200, 7 June 1993). But the Executive Steering Committee considered the lessons learned from the exercise just as important as the specific results: USACERL needed stronger proactive customer-relations initiatives. Consequently, USACERL will bring in senior representatives from all major customer organizations for a full briefing on USACERL's program, and will be invited to present an agenda of concerns for discussion with USACERL senior management. To date, customers briefed include the USACE Assistant Chief of Engineers, the TRADOC Engineer, and ACS(IM).

Accountability and Personnel Linked to Process

TAPES. Several of the Director's TAPES performance objectives hold everyone down the chain of command accountable for focusing on customer needs:

- lead development of the USACERL corporate strategic plan focused on core competencies to support the USACE, ACS(IM), SARD, DUSD-ES strategic visions (30 April 1994), and lead coordination with DRD strategic plan (30 July 1994).
- lead development and coordination of the USACERL business plan focused on technologies to provide products and services to assist customers in meeting their operational and strategic targets in 21XX (30 September 1994).
- oversee planning and execution of USACERL RDTE, Civil Works, customer support, and technical assistance programs to meet needs, milestones, and budgets established in partnership with customers....

Several of the Commander's TAPES performance objectives also cascade down the chain of command to hold employees accountable for customer responsiveness:

- determine customer needs, then ensure that project management focuses on USACERL's research and development activities on realistic and quality products that meet the needs of the Army—on time and on budget.
- seek and promote partnering activities with MACOMs to directly link USACERL's R&D capabilities to issues in the field.

Customer Satisfaction Metrics. As discussed in Chapter II, draft metrics under consideration by the Customer Satisfaction Focus Group include five that hold researchers and managers accountable for customer satisfaction throughout the whole six-step process:

- *Number of Site Visits by Managers.* The visits represent proactive customer outreach by team leaders and above to enhance customer satisfaction during R&D and followup.
- *Number of Phone Checks Routed to Management by Researcher.* The unit of measure is records of phone checks with the customer routed to management to enhance accountability.
- *In-Progress Reviews (IPRs).* The unit of measure will be the number of IPRs routed to management for review, with the minimum requirement set at two (one at 35 percent completion and one at 90 percent).
- *Written Yes-No Satisfaction Survey.* A professional standard survey instrument will be used and impartially reviewed at completion of all projects. The unit of measure would be the percentage of *yes* answers. All answers indicating customer dissatisfaction will be followed up and resolved.
- *Improvement Over Time.* The data souce will be a documented open-ended interview of the customer when the project is complete. The interview will be scored with a broad-scope professional evaluation instrument. Scores and interview data will be deposited in a database and tracked over time.

Incentives. Three incentive awards, being planned or ready for implementation, will recognize individuals and groups for Total Quality and process improvements:

- *The Commander's Quality Excellence Award*
- *Quality Person of the Year Award*
- *Quality Work Group of the Year.*

The awards will recognize TQ as the cement linking employee performance to USACERL's vision, and provide incentives beyond the TAPES process.

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