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Corps of Engineers Technology Adoption Processes (CETAP) Study, Volume I: Executive Summary

by
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Many of the processes used to identify, assess, and incorporate new technologies into U.S. Army Corps of Engineers (USACE) practice are ad hoc, or task-specific and not standardized. Therefore, it is difficult to accurately assess USACE performance in this regard. This report summarizes a study by the U.S. Army Construction Engineering Research Laboratories (USACERL) of USACE procedures for the identification, assessment, and adoption of new technologies. The two basic adoption mechanism types are described: general case mechanisms and project-specific mechanisms. A questionnaire was developed to assess these mechanisms, to identify problem areas, and to establish a benchmark for USACE performance in adopting new technologies. Comparisons of performance were made with outside government and private industry organizations that also completed the questionnaire. Suggestions are presented for improving USACE procedures for incorporating beneficial new technologies into construction operations. The aggressive identification, development, exploitation, and adoption of new technologies will help USACE maintain its excellence in providing the customers and the nation with the best value for their investment.

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Many of the processes used to identify, assess, and incorporate new technologies into U.S. Army Corps of Engineers (USACE) practice are ad hoc, or task-specific and not standardized. Therefore, it is difficult to accurately assess USACE performance in this regard. This report summarizes a study by the U.S. Army Construction Engineering Research Laboratories (USACERL) of USACE procedures for the identification, assessment, and adoption of new technologies. The two basic adoption mechanism types are described: general case mechanisms and project-specific mechanisms. A questionnaire was developed to assess these mechanisms, to identify problem areas, and to establish a benchmark for USACE performance in adopting new technologies. Comparisons of performance were made with outside government and private industry organizations that also completed the questionnaire. Suggestions are presented for improving USACE procedures for incorporating beneficial new technologies into construction operations. The aggressive identification, development, exploitation, and adoption of new technologies will help USACE maintain its excellence in providing the customers and the nation with the best value for their investment.

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FOREWORD

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This work was completed by the Engineering and Materials Division (FM) of the Infrastructure Laboratory (FL). U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. Paul Howdyshell is Chief, CECER-FM, and Dr. Michael J. O'Connor is Chief, CECER-FL. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

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LTC David J. Rehbein is Commander of USACERL and Dr. L.R. Shaffer is Director.

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1 INTRODUCTION

Background

The construction industry is perceived to change only in a slow and evolutionary manner. The introduction, acceptance, and widespread use of innovative materials or methods traditionally takes considerably longer in the construction industry than, for example, in electronics or medicine. It may take several decades for new building materials to capture a significant share of their potential markets.

The identification, assessment and adoption of important new or alternative technologies in the construction missions of the U.S. Army Corps of Engineers (USACE) is most important in assuring that USACE continues to provide quality cost effective facilities. This has been an objective of Headquarters, U.S. Army Corps of Engineers (HQUSACE), for many years.

Two issues confront the Corps relative to the use of new or alternative building technologies in Army construction: (1) the ability to adopt such technologies within the existing USACE environment of regulations, engineering guidance, and standard practice, and (2) the ability to assess the effectiveness of USACE technology adoption procedures, both in an absolute sense and compared to other consumers of facility design and construction services.

Many of the processes currently used to identify, assess, and adopt cost-effective alternative technologies into USACE practice are ad hoc, or task-oriented and not standardized. Therefore, it is difficult to accurately assess USACE performance in this regard. Also, given the large size of the Army's infrastructure and the comparatively small funding available to modernize and maintain it, the aggressive identification, development, exploitation, and adoption of improved technologies offers the Army the opportunity to "do more with less." The Corps must actively promote the use of new materials and technologies that can lower construction costs or improve the durability of facilities. The Corps of Engineers Technology Adoption Processes (CETAP) Study was initiated to address these issues.

Objective

The overall objective of this study is to make detailed recommendations on how the Corps can improve its procedures for the identification, assessment, and incorporation of new and alternative construction technologies.

Approach

The following tasks were established to accomplish the intended objective:

1. Development of an HQUSACE technology-based point of contact directory;

2. Provisions of an inventory of all mechanisms used by USACE for adopting new or alternative technologies into practice;

3. Establishment of a USACE technology adoption benchmark relative to outside Government agencies and private industry;

4. Assessment of USACE technology adoption mechanisms relative to this benchmark, and recommendation of positive changes or new mechanisms to improve the overall system.

Scope

This report summarizes the findings of the CETAP Study and provides basic information on how the Corps compares to other Government agencies and the private sector in the adoption of innovative technologies. This study focused on how the Corps adopts innovative technologies initiated either from within (i.e., by Corps research laboratories or other field operating activities [FOAs] or from without (i.e., by outside government agencies or the private sector.

Chapter 4 includes analysis of some regulations that have been updated or superseded since this study was conducted. These references have been retained because they were part of the regulatory environment affecting technology adoption in the past immediately before this study was begun.

The purpose of the survey of engineering and construction personnel reported in Chapter 5 was primarily to gather qualitative, not quantitative, information. It was determined that only open-ended questions (as opposed to short-answer or true/false questions) could provide the kind of feedback for survey respondents suitable to guide the researcher in making recommendations toward a coherent approach to technology adoption and management.

Definition of Terms

For this study, the terms "new," "alternative," and "innovative" technology refer to any construction material, system, method, or technique emerging in the commercial marketplace, about to emerge, or already commercially available and in use by the private sector but not commonly used by the Corps. (This definition does not include automated data processing hardware or software systems.) These commercially available technologies may also be referred to as "state-of-the-market" technologies (as opposed to "state-of-the-art"). Although the Corps must stay informed about state-of-the-art technologies, these technologies become most important to USACE when they are developed to the point of providing real benefits and approach introduction on the open market.

The term "adoption" is used to include the identification, testing, evaluation, and incorporation into practice of an innovative technology.

Mode of Technology Transfer

It is recommended that the findings of this study become part of future Corps policies and procedures. This could be accomplished through revision of various Engineer Regulations referenced within, and the establishment of new regulations and official policy doctrine.

2 POINT OF CONTACT DIRECTORY

Even before conducting the analysis of technology adoption mechanisms reported in Chapter 3, it was understood that the difficulty of locating an appropriate point of contact can be a major hindrance to product awareness and adoption within a large organization such as the Corps of Engineers. A directory of HQUSACE engineering technical proponents was developed to enable USACE to better direct inquiries concerning innovative technologies. In addition to an alphabetical listing, the directory was also compiled in *Masterformat*, a publication format developed by the Construction Specifications Institute (CSI) and familiar to many of that organization's members. After several drafts and reviews, the directory was turned over to Headquarters for continued maintenance, updating, and official field distribution; a future edition of the directory may include the *Masterformat* section for the convenience of private sector organizations.

3 TECHNOLOGY ADOPTION MECHANISMS

The various technology adoption mechanisms used by the Corps may be defined as one of two basic types: (1) project specific mechanisms or (2) general case mechanisms. A project specific mechanism is any mechanism used to incorporate new technologies into a specific construction project at any time after the decision to build has been made until the project is finished and turned over to the user. General case mechanisms are those procedures used to provide guidance and documentation necessary for the design and construction of future USACE projects. Ideally, a new technology successfully implemented in a project specific case will be appropriately documented for general case considerations.

Project Specific Mechanisms

Before discussing any of the project specific adoption mechanisms in detail, it is important to recognize the processes that these mechanisms affect: (1) military construction, Army (MCA); (2) civil works (CW); and (3) operations and maintenance (O&M). These processes are shown schematically in Figures 1 through 3. As indicated by the circular and rounded oblong figures in the schematics, several opportunities to incorporate new technologies are available during each process. The incorporation could be initiated by the designer, user, reviewer, or contractor. Opportunities for incorporating new technologies are also possible through special programs such as the Value Engineering (VE), Suggestion, and Model District programs. It seems clear that there are ample opportunities to incorporate new technologies into the construction and maintenance cycle. The problem is that the procedures and mechanisms available to accomplish this are either unknown, not well understood, or considered unfeasible to execute by the personnel who would take the action.

Project specific mechanisms include formal procedures (such as the VE program) as well as quasi-formal and informal procedures. (Quasi-formal procedures are those handled in a relatively loose fashion regarding required documentation and the formal approval chain.) The VE program is probably the most well known project specific mechanism, due largely to institutional publicity and related training available through the Corps. VE may be initiated by Corps personnel, architect/engineering firm (A/E) personnel, or the contractors working the project. The adoption of new technology through VE requires formal (or quasi-formal) organizational approval, and the degree of approval required usually depends on the nature of the technology and the degree of risk perceived in its use. (The levels of approval are discussed further in Chapter 4). VE procedures also depend on whether the project is in the design or the construction cycle and whether it is military or civil works construction.

Problems With Project Specific Mechanisms

Several problem areas with the current project specific mechanisms tend to block effective technology adoption. One significant problem is the lack of any overall process or policy that promotes new technology adoption. Although they usually follow existing local office procedures for new technology incorporation, most personnel (including supervisors) do not know when or how the procedures were established or whether the procedures actually follow regulations. What they do know is that when these procedures are needed, they seem to work. In general, personnel may not even be aware that any formal process besides contractor-initiated VE exists.

Time and staffing constraints are also major factors that significantly restrict the adoption of new or innovative technologies by the Corps. Unless informal or quasi-formal approaches are taken, the required documentation and levels of approval (through HQUSACE level in some cases) may take more time than is even available in the project schedule. Extra staffing to help research and document

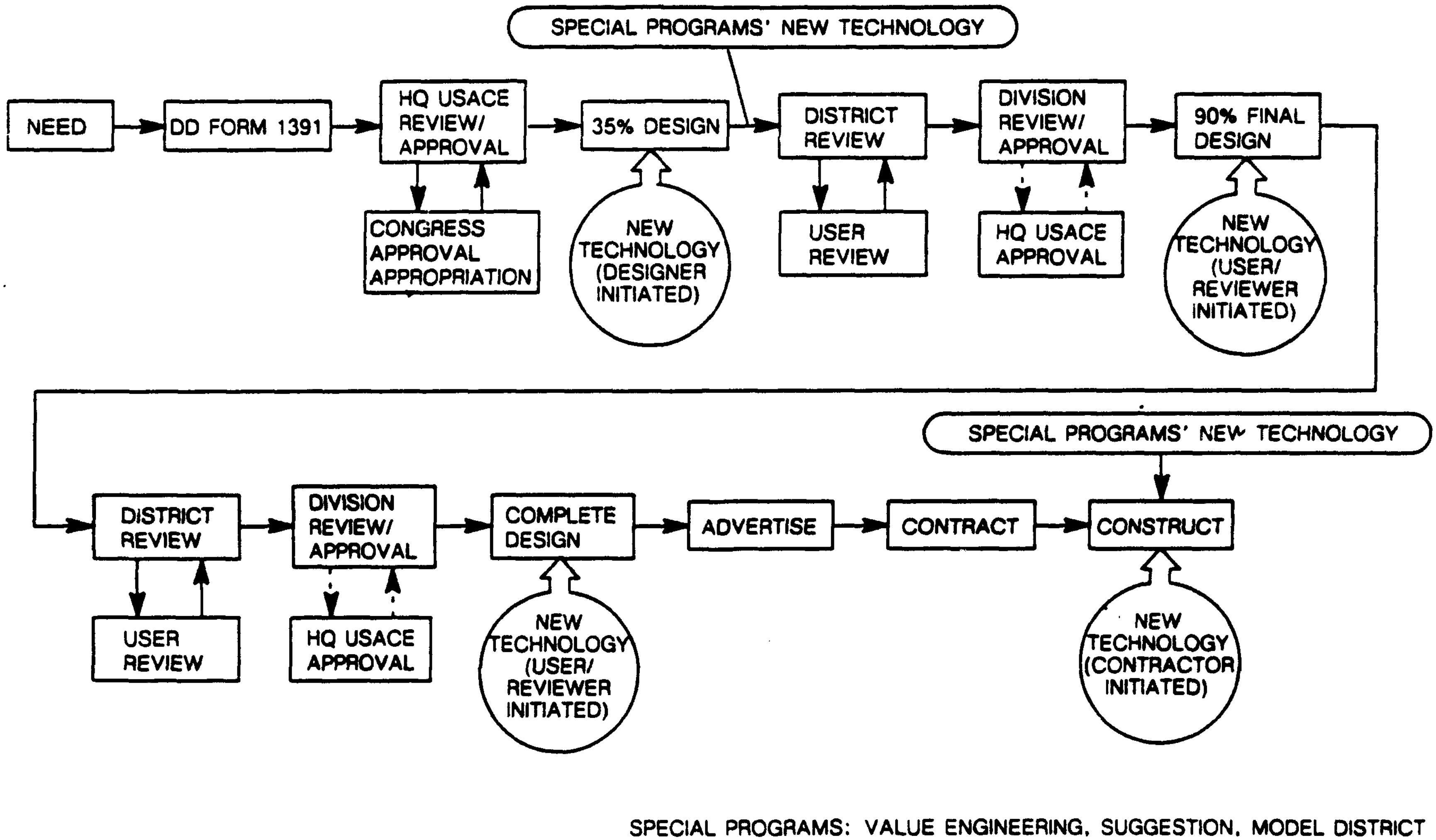

Figure 1. Military Construction Army (MCA) Process.

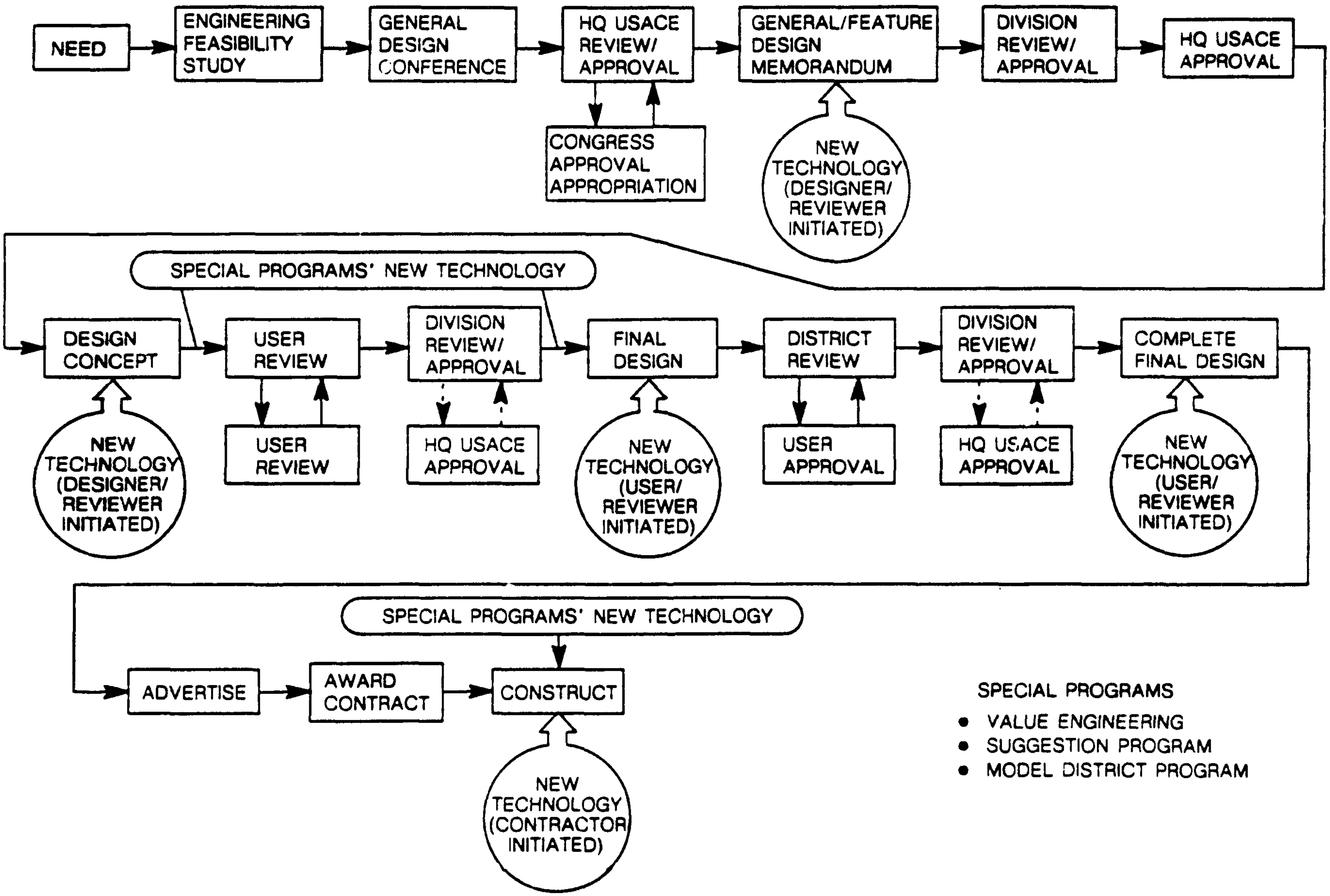

Figure 2. Civil Works Construction Process.

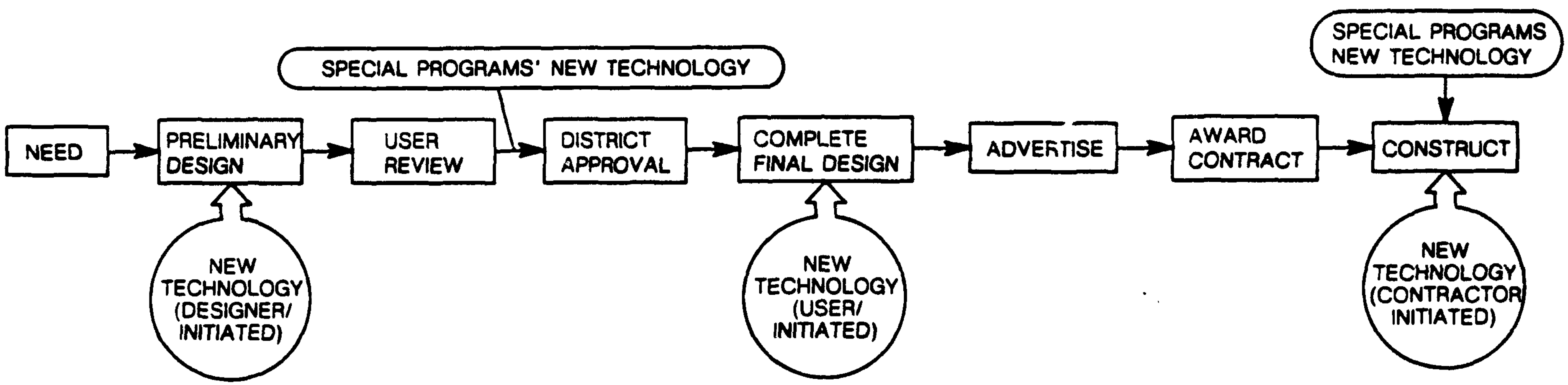

Figure 3. Operations and Maintenance (O/M) Construction Process.

performance claims for potentially useful new technologies could provide some relief, but this is an unlikely solution in the face of shrinking budgets and staffing limits.

A human factor—the resistance to change in general—can also impede the adoption of new technologies. This may take the form of a stubborn faith in established technologies, or perhaps a fear of the unknown. One person in the chain of approval with conservative attitudes about innovation can retard (or even stop) the adoption of a technology. Sometimes this reluctance may arise because the person does not want to be blamed if the technology fails to live up to its expected potential.

Although the ideal situation would be for innovative technologies that have been successfully adopted at the project level to subsequently be incorporated into general case documentation, there are no established mechanisms to effectively accomplish this.

General Case Mechanisms

A general case mechanism can generally be described by a Five-Step Technology Adoption Process as shown in Figure 4. This five-step process is how Corps laboratories introduce techniques they have developed or evaluated into general Corps practice. The first two steps are the research and development (R&D) phase; the last three steps are the technology transfer phase. For a given technology the cycle is not complete until the technology has found general acceptance and use within the Corps.

The Five-Step Technology Adoption Process

Step 1—Determine Army Need. Logically, the first consideration is that the technology should be applicable to Army construction or maintenance needs. For example, technologies for high-rise construction (taller than 10 stories) are not of much interest because the Army does not typically erect such tall buildings.

Step 2—Technology Gap R&D. After a technology has been identified as potentially meeting Army needs, it must be assessed for technology gaps that would require more R&D before Army adoption. This approach has often been referred to as "Smart Buyer" R&D.

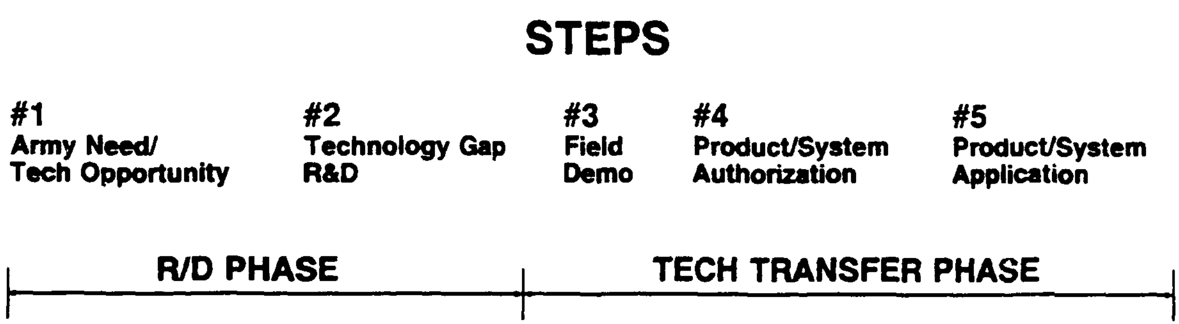

Figure 4. The Five-Step Technology Adoption Process.

Step 3—Field Demonstration. Appropriately developed technologies are field demonstrated in actual-use situations. The field demonstration tests the technology outside the direct controls of the lab and gives potential users the opportunity to become familiar with the technology. The Corps' Facilities Engineering Applications Program (FEAP) and Technology Transfer Test Bed (T^3B) program represent the heart of this important step.

Step 4—Authorization. After a technology has passed the first three steps, complete engineering guidance and/or procurement documentation must be established so the technology can be specified.

Step 5—Application. The final step is to promote general acceptance and use of the technology within the Corps. Marketing activities (e.g., demonstrations, publications, videos, short courses) within the Corps may be necessary for this step to be fully realized.

Subprocesses in Technology Adoption

There are also several supporting processes (or subprocesses) that can affect one or more of the steps of the Five-Step Technology Adoption Process. The four most important are (1) feedback from field experiences, (2) Suggestion Program input, (3) engineering guidance review and updates, (4) the FEAP and T^3B demonstration programs.

Feedback From Field Experiences

Complete communication of field experiences with new technologies may be difficult for a large organization like the Corps to achieve at all levels. However, the importance of feedback from the field cannot be overstressed because it can affect every step in the five-step process. Feedback need not be positive to be useful; information on the negative aspects of a technology can trigger the action necessary to solve a problem and help prevent others from experiencing the same problem. Engineer Form 3078 should be used for communicating this type of information.

Engineering Guidance Review and Update

Step 4 of the five-step process involves the development of guide specifications (or other formal guidance documents) to specify and procure the required process, material, or material system. Huntsville Division is responsible for the maintenance of the Corps of Engineers Guide Specifications (CEGS). Knowing that technologies change through product improvements or obsolescence, Huntsville has within the last 5 years established a CEGS review and updating process. A review is automatically performed every 3 years (assuming enough funds are available). A review cycle of less than 3 years can be triggered if more than five amendments were issued since the last complete review.

Problems With General Case Mechanisms

Four problem areas with general case technology adoption mechanisms have been identified:

1. Five-step process deficiencies

2. Feedback process deficiencies

3. Updating of engineering guidance documents

4. Evaluation and documentation of potentially beneficial new technologies.

The Five-Step Technology Adoption Process is a logical sequence of events for fostering technology transfer and adoption within the Corps. This adoption process is, however, recognized mainly within the Corps laboratories. FOA and HQUSACE personnel also need to be aware of this mechanism, understand its significance, and use the mechanism and policies in their daily activities.

Lack of awareness of and practice of the five-step process are technology adoption deficiencies in an organizational sense, but the process itself also has some deficiencies. In view of their significance to the overall process, Steps 3 and 5 contain some especially significant deficiencies discussed below.

The value of field demonstrations (Step 3) is affirmed through the implementation of the FEAP and T^3B programs. However, to be most effective, field demonstration and technology transfer activities require an appropriate level of participation by the researchers who developed or evaluated the technology. Such participation is limited by insufficient funding for these demonstration projects. By virtue of working within the construction industry, Corps R&D laboratories must operate differently than the Army Materiel Command (AMC) laboratories developing weapons or intelligence systems. A broadened mission statement directing Corps laboratories to actively participate in the technology transfer process, along with supporting Research, Development, Test, and Evaluation (RDTE) advanced development funding, is needed to enhance the effectiveness of field demonstrations.

Step 5 (application of the technology) of the five-step process is not fully accomplished until the technology is used on a common basis (i.e., adopted). Successful demonstration and documentation of a technology do not mean that the technology will be automatically used. A field demonstration may make a few people or field offices comfortable with the technology, but this does not mean others will share the same enthusiasm. Step 5 requires "after-demo marketing" to speed the process along. Such marketing could include special training, sessions, seminars, product brochures, and/or additional demonstrations.

With a 3-year update cycle, guide specifications will probably not be too far out of date. Concerns remain, however, about whether new technologies are given adequate considerations during these review cycles. Also, no positive link exists between the demonstration tests and the CEGS review and update. Serious coordination problems exist between some CEGS and their corresponding technical manuals (TMs) or engineer manuals (EMs). The Corps is responsible for CEGS while other agencies (or multiple agencies in the case of tri-service documents) may have proponency for the corresponding TMs. Misleading or conflicting information can result when corresponding guidance documents are not updated on a similar schedule. (This problem is discussed further in Chapter 5.)

The adoption of many new technologies is retarded either because the appropriate personnel (e.g., project designer, specification writer) are not completely familiar with the technology or have no way to verify performance. At the FOA and HQUSACE levels, identification and subsequent promotion of new technologies is undertaken, but it is not systematic, consistent, or even a mission requirement. Currently, if laboratory evaluations are required because of questions about a technology's performance, the office identifying these needs is required to fund this evaluation, even if it is performed at a Corps laboratory. Because of their 6.1 and 6.2 RDTE funding, the Corps R&D laboratories have a mission that does not include exploratory product performance evaluations. A mechanism (including funding sources) is needed to provide "smart buyer" evaluations of innovative technologies identified as potentially beneficial but lacking performance verification.

4 REGULATIONS AFFECTING TECHNOLOGY ADOPTION

Technology Transfer Factors

A review of Corps documents indicates that a variety of policy documents govern some of the procedures used by the Corps for introducing innovative technologies, but there is no single source that provides a summary or collection of this guidance. Figure 5 shows five categories of technology transfer factors that help focus the following assessment of Corps regulations by assuring that the common channels of introducing innovative technologies are properly considered. The following is a brief explanation of each category, associated factors, and the major policy topics relevant to each category.

Source of Inquiry

The source of inquiry is defined as the individual or organization that initially makes the inquiry to the Corps about introducing an innovative technology to the Corps of Engineers. The most common sources of inquiry are those listed under that heading in Figure 5, and include sources from both within the Corps and from the outside. The policy issues in this category deal with policy and procedures that directly or indirectly promote the introduction of innovative technologies to the Corps.

Initial Contact/Action Office

This category lists the various organizations within the Corps, Department of the Army (DA), U.S. Department of Defense (DOD), Congress, and others that either initially receive the inquiry or serve as the action office responsible for assessing the applicability of the proposed technology to the Corps. The major policy issue in this category is the identification and distribution of points of contact (POCs) or proponents for the various areas of technical interest. When an inquiry is made anywhere within the

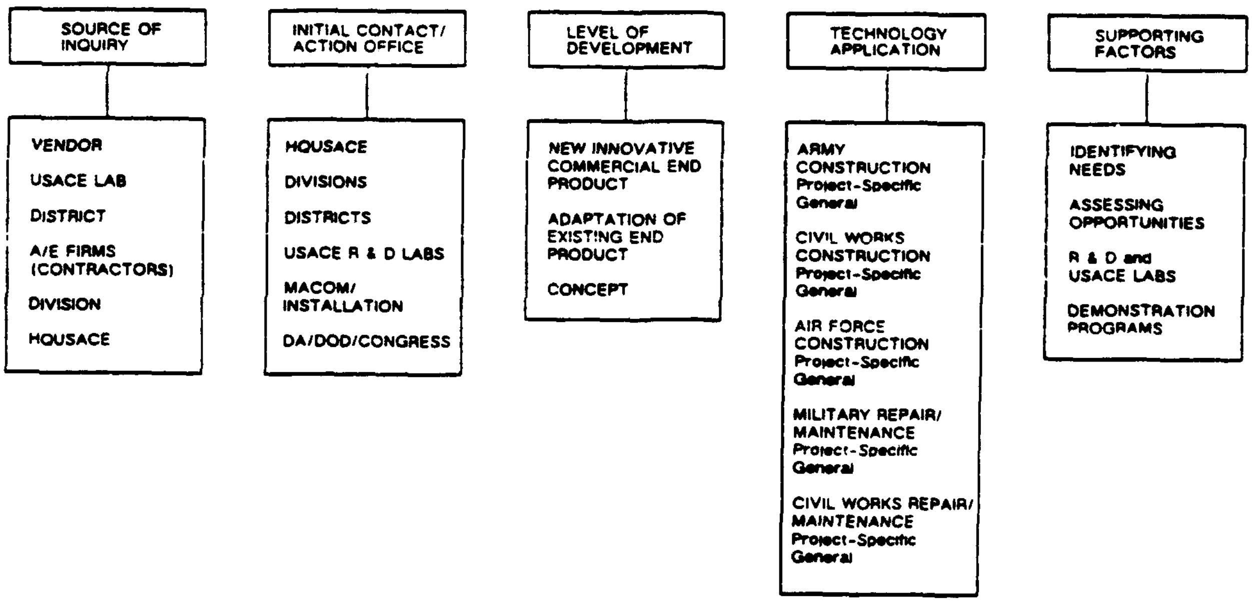

Figure 5. Technology Transfer Factors.

Corps, the person handling the initial inquiry should forward the inquiry to the correct point of contact or proponent.

Level of Development

This category is divided into three sublevels to distinguish the degree of technology development: (1) an end product for a given application, (2) a new or modified application of an existing technology, and (3) a concept or idea. The same action office should handle policy issues for a given technology regardless of the level of development.

Technology Application

Technology application is divided into the major engineering, construction, and maintenance and repair (M&R) activities that the Corps is involved in. Each of these may be subdivided into general and job-specific applications. The policy issue in this category deals with the deviation from standard criteria, and the procedures for changing standard criteria.

Supporting Factors

The supporting factors include pertinent policies that have a significant impact on the introduction of innovative technologies to the Corps but are not necessarily inherent in, or exclusive to the Corps' engineering, construction, and M&R missions.

Corps Policies and Procedures That Affect Technology Adoption

The categories of policy documents listed below were searched to determine which ones affect the introduction of innovative technology into the Corps practice:

DOD Manuals
DOD Directives
Army Regulations (AR)
Engineer Regulations (ER)
Technical Manuals (TM)
Engineer Manuals (EM)
Engineer Circulars (EC)
Engineer Pamphlets (EP)

Table 1 lists specific regulation and policy documents that affect the adoption of innovative technology into Corps practice. The following sections summarize the same policy and regulatory information for the factors and categories listed in Figure 5. The purpose of analyzing the policies and regulations in this fashion is to identify any areas for which regulations do not exist.

Sources of Inquiry

Inquiries to the Corps about introducing innovative technologies can be initiated from almost any source. Although there is no real restriction on who makes the initial inquiry, there are specific policies that promote such inquiry. The Value Engineering Program (EP 11-1-3 and EP 11-1-4), Technical Centers of Expertise (ER 1110-1-262), and the Corps Laboratories (EP 1-1-10)[1] are three examples.

The regulation that establishes the technical centers of expertise (TCX), ER 1110-1-262, clearly states that each TCX is responsible for maintaining state-of-the-art technical competence in its assigned specialty.

Corps laboratories by virtue of their R&D mission, are inherently a major source of inquiry regarding innovative technologies in Corps practice. In fact, a significant number of Corps regulations and policies support the adoption of innovative technologies that have evolved from laboratory R&D programs. (These regulations are discussed in more detail in the *Supporting Factors* section of this chapter.)

Initial Contact/Action Office

All of the organizations listed under this category have been used as initial contact points for introducing innovative technology to the Corps of Engineers. The object of designating an initial contact is to assure that the individual with whom contact is made knows (or can easily find out) who has the action responsibility for the specific proposed inquiry. A review of current regulatory and policy documents indicates that no single document specifically lists action offices for the various common types of inquiries related to innovative technologies that the Corps handles.

Two documents that provide some assistance in locating an action office are ER 1110-1-262 and EP 70-1-3. ER 1110-1-262, as described in the previous section of this chapter, details that TCXs have the responsibility of maintaining state-of-the-art technical competence in their assigned specialty. EP 70-1-3 contains a list of technology capabilities in Corps laboratories, and provides a specific list of contacts by technical area listed.[2] This list was developed to provide Army installations in need of technical support with a directory of Corps laboratory capabilities. This same kind of list could be used for identifying laboratory or Corps-wide POCs. As with the TCXs, it can also be assumed that most laboratory POCs will know who has the action responsibility for their specific area of expertise.

Level of Development

As previously stated, Figure 5 contains three levels of product development. Corps policy and procedure documents do not specifically differentiate these product levels or who has the action responsibility for adopting new products.

Current Corps policy for the use of unusual or new methods and materials in military construction (ER 1110-345-100) states that "if a material previously untried for military construction is proposed by the industry for use in place of an accepted material, or as an option, it will be the responsibility of the manufacturer to prove the merit of the product..."[3] This statement implies that only new or alternative end products with an existing database sufficient to validate the merit of the product should be proposed for a specific military construction project. The Civil Works regulations, ER 1110-2-1150 and ER 1110-2-1200, are not specific in this area, but if the Corps chooses to bear the burden of validating the merits of

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[1] EP 11-1-3, *Value Engineering Officer's Operational Guide* (HQUSACE, 15 June 1976); EP 11-1-4, *Value Engineering Benefits and the Construction Contractor* (HQUSACE, 1 April 1981); ER 1110-1-262, *Corps-Wide Technical Center of Expertise Assigned to Divisions and Districts* (HQUSACE, 31 July 1985); EP 1-1-10, *Corps of Engineers Laboratory, Investigational, Research and Testing Facilities* (HQUSACE, 1 May 1985).

[2] EP 70-1-3, *Installation Support/One-Stop Service* (HQUSACE, 30 May 1989).

[3] ER 1110-345-100, *Design Policy for Military Construction* (HQUSACE, 14 December 1973), par 9.

Table 1

Regulation and Policy Documents That Affect Adoption of Innovative Technologies Into USACE Practice

Regulation Reference	Regulation Title	Date
ER 10-1-3	Divisions and Districts	28 November 1986
ER 10-1-8	U.S. Army Engineer Waterways Experiment Station	15 July 1985
ER 10-1-25	U.S. Army Cold Regions Research and Engineering Laboratory	30 July 1987
ER 10-1-26	U.S. Army Construction Engineering Research Laboratory	28 July 1987
ER 10-1-45	U.S. Army Engineer Topographic Laboratories	25 October 1987
ER 37-1-18	Conferences and Workshops	14 July 1988
ER 70-1-5	Corps of Engineers Research and Development Program	28 November 1980
ER 70-2-6	Identification of Civil Works Research Needs	5 January 1982
ER 70-3-2	Military Construction Research Requirements and Research and Investigations Coordination in Field Activities	30 June 1971
ER 70-3-9*	Management and Execution of the U.S. Army Corps of Engineers Military Research, Development, Test and Evaluation (RDT&E) Program	31 March 1989
ER 415-1-13	Design and Construction Evaluation (DCE)	1 September 1987
ER 415-3-11	Post Completion Inspection Feedback	28 September 1984
ER 415-345-270	Administration and Regulation for Cost-Plus-A-Fixed-Fee Construction Contracts	1 July 1968
ER 1105-2-10	Planning Programs	18 December 1985
ER 1110-1-262	Corps-Wide Technical Centers of Expertise Assigned to Divisions and Districts	1 July 1985
ER 1110-2-1150	Engineering After Feasibility Studies	15 November 1984
ER 1110-2-1200	Plans and Specifications	12 June 1972
ER 1110-345-100	Design Policy for Military Construction	14 December 1973
ER 1110-345-720	Specifications	31 October 1989
ER 1130-2-417	Major Rehabilitation Program and Dam Safety Assurance Program	30 November 1980
EP 1-1-10	Corps of Engineers Laboratory, Investigational, Research and Testing Facilities	1 May 1985
EP 11-1-3	Value Engineering Officer's Operational Guide	15 June 1976
EP 11-1-4	Value Engineering Benefits and the Construction Contractor	1 April 1981
EP 70-1-3	Installation Support/One Stop R&D Service	30 May 1989
AR 34-2	Rationalization, Standardization, and Interoperability Policy	15 December 1980
AR 70-1	System Acquisition Policy and Procedure	10 October 1988
AR 70-15	Product Improvement of Material	15 June 1980
AR 71-9	Material Objectives and Requirements	20 February 1987
AR 415-10	Military Construction - General	1 March 1984
AR 415-15	Military Construction Army (MCA) Program Development	1 December 1983
AR 415-18	Military Construction Responsibilities	1 September 1982
AR 415-20	Project Development and Design Approval	15 March 1974
AR 420-70	FE Buildings and Structures	17 November 1976
AR 700-50	Development and Use of Non-Government Specifications and Standards	15 July 1977
AR 700-90	Army Industrial Preparedness Program	13 March 1986
DOD 4270.1-M	Department of Defense Construction Criteria Manual	1 September 1987
AFM 88-15	Air Force Design Manual - Criteria and Standards for Air Force Construction	January 1975
AFR 88 15	Criteria and Standards for Air Force Construction, Interim Draft Ed.	January 1986
AFR 89-1	Design and Construction Management	November 1988
AFR 93-8	Applications Engineering Program	July 1980
AEI	Design Criteria	9 December 1991

Note: AEI = Architectural and Engineering Instructions
AFM = Air Force Manual
AFR = Air Force Regulation.

* Superseded ER 70-1-9, *Transfer of Corps of Engineers Research and Development Technology* (HQUSACE, 28 November 1980), which was in effect over most of the period relevant to this study.

an innovative technology, the cost and resources required must be included in the Plan of Action document for approval by the Division Commander.[4]

Technology Application

This category is divided into the three major users of Corps engineering and construction, and the two users of maintenance and repair criteria. For Army construction, ER 1110-345-100 and ER 1110-345-720 provide specific policy guidance for the use of new materials and methods. The policy states that "unusual or new materials or methods of construction may be specified if merit has been established and use has been approved by the Division Engineer."[5] Merit is defined as in the best interest of the Government from the standpoint of economy, lower life cycle cost and quality of construction. As indicated in the section on level of development, it is the responsibility of the manufacturer to prove the merit of a new material or method. In addition, ER 1110-345-100 references a series of ARs that the ERs must comply with. AR 415-20 clearly states the relationship between the using service and the Corps of Engineers in the planning and design of Army facilities: the using service has the responsibility of establishing facility functional requirements whereas the Corps of Engineers has responsibility for all design activities starting with the design criteria requirements.[6] The AR implies that the using service has little authority in proposing technical criteria alternatives, but does have numerous opportunities to comment on and review the Corps design. Thus, the using service has no authority to mandate the use of innovative technology but can suggest that the Corps consider such technologies in their project design.

At the Department of Defense level, DOD Manual 4270.1-M clearly states that "new materials and techniques of construction, which can be conclusively shown to have produced satisfactory results in actual use, shall be considered in the design of new facilities. However, use of promising new materials and techniques on a trial basis is encouraged."[7]

The design and construction criteria for civil works facilities are presented in ER 1110-2-1150 and ER 1110-2-1200. Engineering design and criteria methods described in ER 1110-2-1150 state that "engineer manuals and regulations in the 1110-1- and 1110-2- series are the basic technical guidance for design and construction of civil works projects.... Advance approval of HQUSACE will be obtained for any significant departure from those criteria indicated as mandatory in the manuals and regulations."[8] All civil works projects at the general design and feature design memorandum stage are approved by the Division Commander, with HQUSACE holding approval for certain technologies such as pumping plants, spillways, and corrosion mitigation. Thus, all innovative technologies proposed for civil works construction must be approved by the Division Commander or Headquarters (unlike military construction, where such approvals may be made much closer to the working level).

ER 1110-345-100 states that "Division and District Engineers are encouraged to inform DAEN-MCE of suggested changes to standard designs (both drawings and specifications) considered desirable to improve construction or functional use or to effect savings. Such information will include suggested improvement based on local experience and suggested optional materials and methods of construction. ENG Form 3078 will be used for reporting."[9] Paragraph 9 of this regulation allows the use of unusual

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[4] ER 1110-2-1150, *Engineering After Feasibility Studies* (HQUSACE, 15 November 1984); ER 1110-2-1200, *Plans and Specifications* (HQUSACE, 12 June 1972.)

[5] ER 1110-345-100, par 9; ER 1110-345-720, *Specifications* (HQUSACE, 31 October 1989), par 10.

[6] AR 415-20, *Project Development and Design Approval* (HQUSACE, 15 March 1974).

[7] DOD Manual 4270.1-M, *Department of Defense Construction Criteria* (DOD, 15 December 1983). This manual has been incorporated into Military Handbook 1190, *Facility Planning and Design Guide* (DOD, 1 September 1987). However, DOD Manual 4270.1-M is cited because it was the document actually in effect for most of the period preceding the CETAP study.

[8] ER 1110-2-1150, par 7.

[9] ER 1110-345-100, par 21c.

or new methods or materials previously untried for military construction if it can be shown that it is in the best interest of the Government. It also provides for, upon request from HQUSACE, an evaluation handout to assist in the evaluation of that merit.[10] ER 415-3-11 provides the general policy and procedures relating to feedback of information from field engineering and construction sources, and the processing and dissemination of such feedback information to appropriate levels of command.[11] Specific systems described in this policy are the Engineering Improvement Recommendation System (EIRS), the post-completion inspection (PCI), engineering and design coordination team visits, and the Design Criteria Feedback Program (DCFP).

The ability of the various feedback systems presented in ER 415-3-11 to assist in the introduction of innovative technologies is directly affected by the willingness of the Corps to try such technologies.

Supporting Factors

Included in this category are a variety of factors that obviously affect the introduction of innovative technologies but are not necessarily directly related to the engineering, construction, or M&R processes. These include identification of needs, assessment of opportunities, research and development activities, and demonstration programs.

ER 415-3-11 provides an extensive program for identifying, reporting, and disseminating information on guidance and criteria for military construction in a timely fashion to all FOAs. It should be noted, however, that for civil works there is no counterpart for this regulation. ER 1110-2-100, which provides a policy for periodic inspection of civil works structures, does not cover feedback on design criteria or specifications.[12]

In support of Corps R&D initiatives, formal procedures have evolved for identifying research needs in both civil works and military construction. ER 70-2-6 and ER 70-3-2 describe respectively the civil works and the military construction research needs policies. ER 70-3-2 is obsolete, however, and does not represent the current procedure and documents used to identify military construction R&D requirements.[13]

Other Policy Impacts

The opportunity to adopt certain technologies is limited by ER 1110-2-1200, which requires that nationally recognized industry and technical society specifications and standards shall be used to the maximum extent practicable to assure that requirements are compatible with current industry practices. If no suitable industry documents apply, then Federal or military specifications and standards are to be used. This policy could make the adoption of some technologies dependent on factors outside USACE.

Full-scale field demonstrations of Corps-developed technology also promote the transfer of innovative technologies to Corps clients. Such programs, including FEAP and T^3B have evolved as part of the base support mission area because of the lack of advanced development (level 6.3 and higher) funding in this area. FEAP demonstrates technologies applicable directly at Army installations, and the T^3B program demonstrates technologies applicable to Corps military construction activities. An

[10] ER 1110-345-100, par 9.

[11] ER 415-3-11, *Post Completion Inspection Feedback* (HQUSACE, 28 September 1984).

[12] ER 1110-2-100, *Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures* (HQUSACE, 8 April 1988).

[13] ER 70-2-6, *Identification of Civil Works Research Needs* (HQUSACE, 5 January 1982); ER 70-3-2, *Military Construction Research Requirements and Research Investigations Coordination in Field Activities* (HQUSACE, 30 June 1971).

engineering regulation establishing specific policy for these demonstration programs has not evolved, nor are there regulations that provide policy for demonstrations funded from other sources. Thus, although the Corps has been involved in a variety of demonstration activities, there is no specific HQUSACE policy or procedure that defines what constitutes a demonstration or what happens after the demonstration has been completed. Also, these demonstrations are observed only by a few personnel, usually only by those tasked to assist in the project.

Policy Gaps and Deficiencies

Several policy gaps were identified during this research:

1. A list of Corps contacts or proponents for assessing innovative technologies does not exist.

2. There is no policy relative to demonstration projects funded by FEAP, T^3B, or any other source.

3. The current policy on military construction research needs is obsolete and needs revision to comply with current procedures.

4. There is no feedback policy for civil works engineering and construction criteria.

5. Policy documents do not specifically recognize the various levels of technology development or who has action responsibility.

In addition to the preceding list, a general deficiency is that Corps policy on the introduction of innovative technologies is spread throughout a very diverse set of documents. For example, Table 1 lists 39 documents, each of which contain some specific guidance that affects the way the Corps introduces innovative technologies. Thus, some form of document summarizing the Corps' overall technology adoption policy and referencing the appropriate existing policy documents should be useful in developing a general and consistent understanding of the Corps technology adoption process.

5 BENCHMARK DETERMINATION AND COMPARISON TO OTHERS

Background

One task of this research was to establish a benchmark for comparing the Corps' performance in the adoption of innovative technologies to comparable agencies in the public and private sectors. A series of questionnaires was developed to assist in the establishment of this benchmark. The University of Illinois Survey Research Laboratory, Urbana, IL, was contracted to help develop these questionnaires. Each questionnaire was divided into four sections to address the following main issues:

1. Who is responsible for the introduction of new technologies?

2. What are the procedures for introducing new technologies?

3. How is information on new technologies disseminated?

4. How effective are the procedures for introducing new technologies?

To help provide some quantification for each of the four main topic areas, each area had at least one question asking the respondents to numerically rank the performance of their respective organization relating to that topic issue. In those questions a rating scale of 1 to 5 was used, with 1 meaning poor performance and 5 meaning excellent performance.

Table 2 is a list of the Corps Districts and Divisions, government agencies, and private industry organizations that participated in the study by filling out questionnaires and providing the interviews. The private industry firms were selected on the basis of having design, construction, or maintenance responsibilities similar to those of the Corps. Three versions of the basic questionnaire were developed: one edition was tailored to the Corps of Engineers, one to the U.S. Army Directorate of Engineering and Housing (DEH), and one to nongovernment and private industry organizations. The same basic questions were asked in each version, but specific Corps organizational references were removed from the appropriate versions. To provide the viewpoint of organizations that have dealt with the public and private sectors as a supplier of new technologies, another questionnaire was developed to survey various vendors. The list of surveyed vendor firms is shown in Table 3. Those chosen included some that have been successful and some that have not been successful in having their new technologies adopted on Corps projects.

Responsibility for Introducing New Technologies

A summary of the responses to a question about the organizational push for the introduction of new technologies is shown in Figure 6. Although the average (mean) effectiveness ratings are reasonably close for the Corps (X=3.2) versus the private sector (X=3.8), the distribution of responses is very interesting. Based on these responses, it appears that private sector respondents perceive that their organizations promote the use of new technologies to a greater extent than do their counterparts in the Corps. Most Corps personnel surveyed were not aware of any specific organizational policies on the use of innovative technologies.

Procedures for Introducing New Technologies

Survey results revealed some interesting items regarding Corps FOAs' interpretation and execution of the regulations covering the adoption of new technologies. For example, most of the FOA respondents were unfamiliar with the provisions of the relevant ERs (except the VE program).

Table 2

Locations Surveyed

Headquarters U.S. Army Corps of Engineers

Corps Field Operating Activities

- Albuquerque District
- Baltimore District
- Detroit District
- Kansas City District
- Little Rock District
- Lower Mississippi Valley Division
- Louisville District
- Mobile District
- Missouri River Division
- Norfolk District
- Omaha District
- Ohio River Division
- Sacramento District
- Seattle District
- South Atlantic Division
- Vicksburg District

Non-Corps Government Agencies

- Capital Development Board (State of IL)
- General Services Administration
- Naval Facilities Engineering Command (Great Lakes, IL; Norfolk, VA; San Bruno, CA)
- U.S. Veterans Administration

Directorates of Engineering and Housing

- Fort Eustis, VA
- Fort Hood, TX
- Fort Knox, KY
- Fort Lewis, WA
- Fort Ord, CA
- Fort Rucker, AL
- Fort Sill, OK

Private Industry Organizations

- Bechtel Civil Inc.
- Bethlehem Steel
- Fluor Daniel
- General Motors (Argonant Division)
- GTE Service Corp.
- IBM
- Marriott Corp.
- Tishman Research Corp.
- Xerox Corp.

Table 3

Vendors Surveyed

Alside, Inc.
A.W. Chesterton
Belzona Molecular
Glidden
Norandex, Inc.
Omega Engineering, Inc.
U.S.G.
U.S. Steel
W.R. Grace Co.

When asked to identify the greatest hindrance to the processes used to incorporate new technologies into use, 60 percent of the Corps respondents who answered pointed to the various long and involved review and approval processes. (Generally, a project schedule does not allow time for any approval process beyond the local office.) Thirty percent of the respondents said time and staffing constraints were the major hindrances.

Several Corps respondents said they believe the VE program is worthwhile by encouraging the Corps/Army to use and benefit from alterative materials, material systems, and technologies. However, nearly an equal number of respondents stated that the VE program was far too often just an opportunity for the contractor to profit from substituting inferior materials on a job.

Some survey questions addressed the influence of CEGS on the adoption of innovative technologies. Several expressed the opinion that anything not in the Guide Specifications is not allowed to be used on Corps projects. (Two people from different offices admitted that this response is sometimes used as a "cop-out" when someone suggests a technology not in the guide specifications but no one has time to evaluate it. Others felt that CEGS are too restrictive, and that following them too closely "stifles" their ability to use new technologies. Approximately 50 percent of the Corps employees surveyed said they believe CEGS do not reflect the state of the art. (Although the questionnaire used the phrase "state of the art," the term was defined for participants to mean "state of the *market*" in accordance with the definition of terms in Chapter 1.) About 30 percent of the Corps respondents stated that, for the most part, CEGS do reflect the state of the art. The remaining respondents were noncommittal on this question. None of the respondents was aware of the automatic CEGS update and review cycle.

Several FOAs also gave examples where the CEGS and the corresponding TMs and EMs for that technology are not consistent. Usually TMs and EMs are several years out of date, and may even contradict the CEGS.

(SELF-ASSESSMENT BY RESPECTIVE GROUPS)

1 = Strongly Disagree (doing a poor job)

5 = Strongly agree (doing an excellent job)

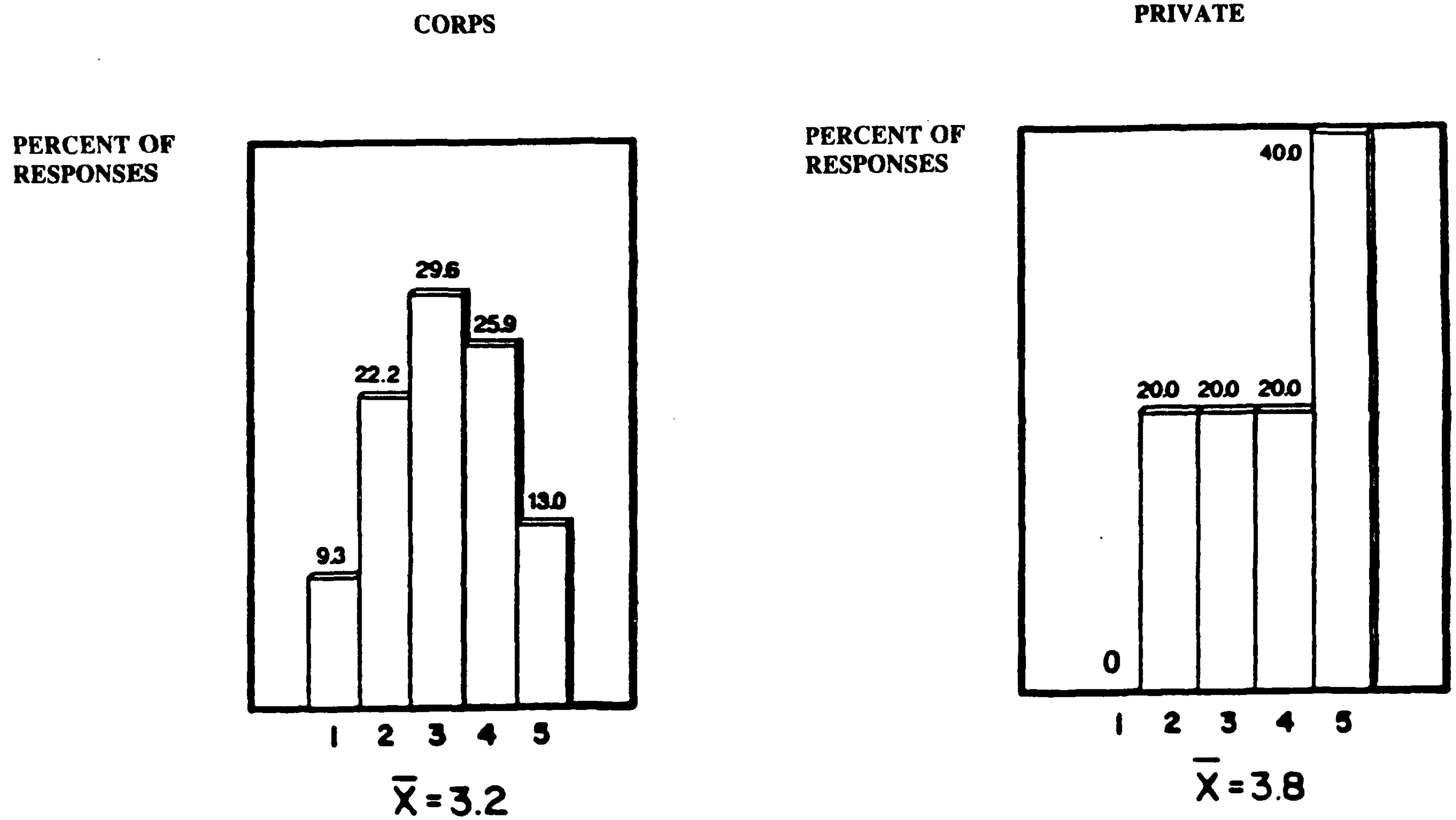

Figure 6. Assessment of Organized Push for Introducing New Technologies.

Disseminating Information on New Technologies

The questionnaires revealed that most of the Corps personnel surveyed felt that feedback was a major problem in the adoption of new technologies. Most stated that communication deficiencies exist in every direction within the Corps hierarchy. In particular, feedback (e.g., case histories, lessons learned) from field experiences with new technologies is considered unsatisfactory. Personnel are reluctant to communicate failure and yet have little time to properly document their successes. The result, however, is that others in the Corps who need such information do not receive it.

Most Corps respondents said that Engineer Form 3078, "Design or Project Deficiency Report and Recommendation," is ineffective in communicating information on specific field applications. One respondent stated that he no longer bothers with the 3078 since it appeared no one paid any attention to them anyway. Civil Works personnel were unfamiliar with this form and do not use anything like it.

Figure 7 summarizes the responses by both engineering and construction personnel to a question on the effectiveness of Corps procedures for the dissemination of information. About 40 percent of the construction personnel interviewed rated these procedures as poor because of inadequate communication of field experiences back through the organization.

Effectiveness of the Procedures for Introducing New Technologies

The survey indicated that most Corps personnel believe there are few incentives to make the extra effort usually required to become an all-out champion for a new technology. Some respondents listed professional recognition and monetary awards from suggestion programs as incentives, but monetary awards currently available were not considered to be significant. On the other hand, private industry personnel listed monetary awards (sometimes up to 50 percent of their annual salary) as their top incentives available for promoting new technologies. Table 4 summarizes responses on incentives.

The top two deterrents to the adoption of new technologies by both the public (including non-Corps Government agencies) and the private sectors were the same: (1) risk (unknown performance) and (2) time constraints (Table 5). The narrative answers from the questionnaires, however, revealed significant differences in the meaning of these answers between the two groups. The private sector would often spend the extra time (i.e., over and above normal expected performance) to research the available information in order to minimize risk* and develop accurate expectations about performance. Although

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* The issue of risk as a deterrent to the adoption of innovative technologies applies to A/E contractors as well as Corps personnel. A/E risks and opportunities must be considered in the context of USACE guidance and direction. An A/E firm under contract with USACE will ultimately assume responsibility for the integrity of a facility's design. If USACE design reviewers are not comfortable with an innovative product being promoted by an A/E, it is unlikely the item will be approved.

Likewise, if USACE personnel promote a new or innovative technology, the A/E must be equally confident in its use and anticipated performance in order to assume that responsibility. If the A/E does not concur with such a recommendation, it is unlikely that an FOA will mandate the use of the item. Even in the established practice of value engineering, an A/E's acceptance of VE study recommendations is generally voluntary. An FOA will generally not mandate VE recommendations over an A/E's objection. The mitigation and/or transfer of risk must be addressed both in the technical communications between Corps and contractor and in the composition of the contract itself.

Another deterrent to A/E promotion of innovative technologies can be attributed to the current design services fee structure, which does not allow an A/E firm to conduct extensive product research during design development. Also, exploration of innovative technologies is further discouraged (at least implicitly) with the extensive engineering guidance the Corps provides contractors. Such extensive guidance may imply that a technology is "acceptable" and "safe" to the Corps.

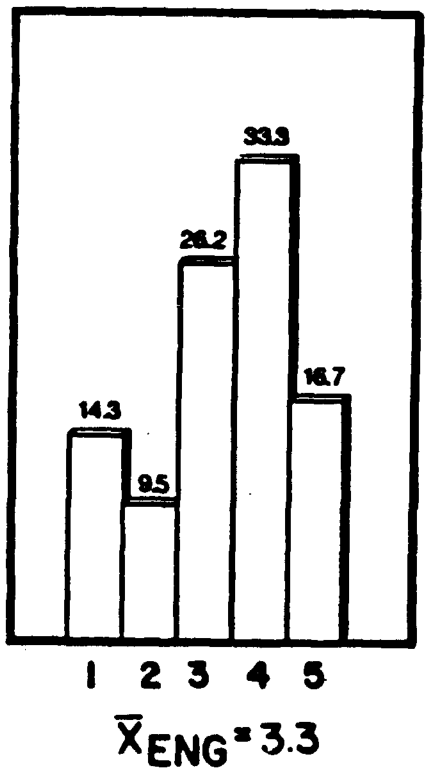
(SELF-ASSESSMENT BY RESPECTIVE GROUPS)

1 = Strongly disagree (doing a poor job)

5 = Strongly agree (doing an excellent job)

ENGINEERING PERSONNEL

PERCENTAGE OF RESPONSES



CONSTRUCTION PERSONNEL

PERCENTAGE OF RESPONSES

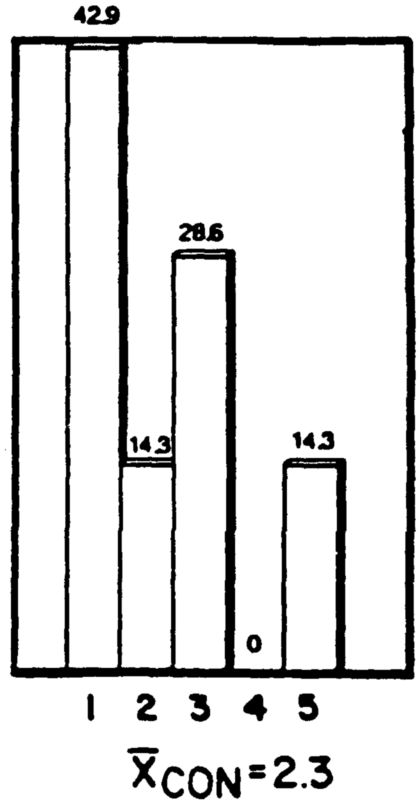


Figure 7. Assessment of Processes to Disseminate Information.

Table 4

Incentives To Use Innovative Technologies (in Design Phase)

Corps/Government Agencies	**Private Sector**
None	Monetary Awards
Professional Recognition	Cost Savings
Monetary Awards	Repeat Business
Self Satisfaction	Professional Recognition
Customer Need	None

NOTE: Survey responses are listed in descending order from most common to least common.

Table 5

Deterrents to Using Innovative Technologies (in Design Phase)

Corps/Government Agencies	**Private Sector**
Risk, unknown performance	Risk, unknown performance
Time constraints	Time constraints
Level of effort necessary	Cost (need for profit)
Guide specifications	Resistance to change
Resistance to change	None

NOTE: Survey responses are listed in descending order from most common to least common.

Corps personnel exhibit high levels of professional integrity and initiative, numerous institutional disincentives greatly discourage their extra effort. Survey responses indicate that public-sector personnel widely perceive that the disincentives for extra effort far outweigh the potential rewards. In the private sector the rewards can be substantial thereby encouraging an "above and beyond" effort.

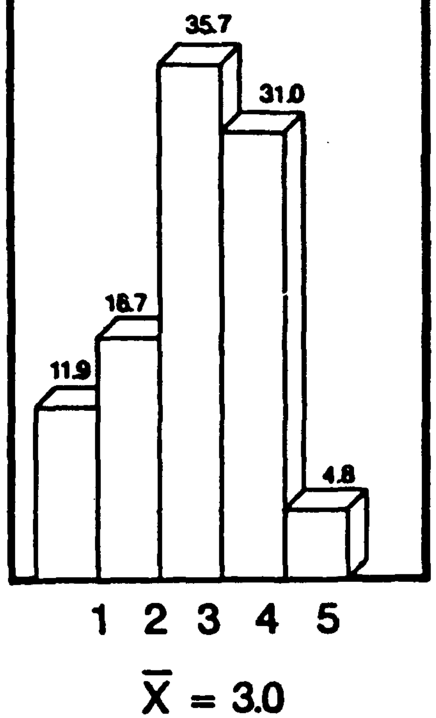
Figures 8 and 9 compare how various categories of survey respondents ranked their respective organizations' overall effectiveness at adopting innovative new technologies while assuring the construction of reliable, low-maintenance facilities. Figure 9 shows that engineering personnel believe the Corps is effective in this regard while over half of the construction personnel responding said the Corps could be doing much better. With an average rating of 4.5 (Figure 9), the private sector respondents perceive their organizations as very effective at adopting innovative technologies into construction and maintenance activities.

(SELF-ASSESSMENT BY RESPECTIVE GROUPS)

1 = Strongly disagree (doing a poor job) 5 = Strongly agree (doing an excellent job)

ENGINEERING PERSONNEL

PERCENTAGE OF RESPONSES



CONSTRUCTION PERSONNEL

PERCENTAGE OF RESPONSES

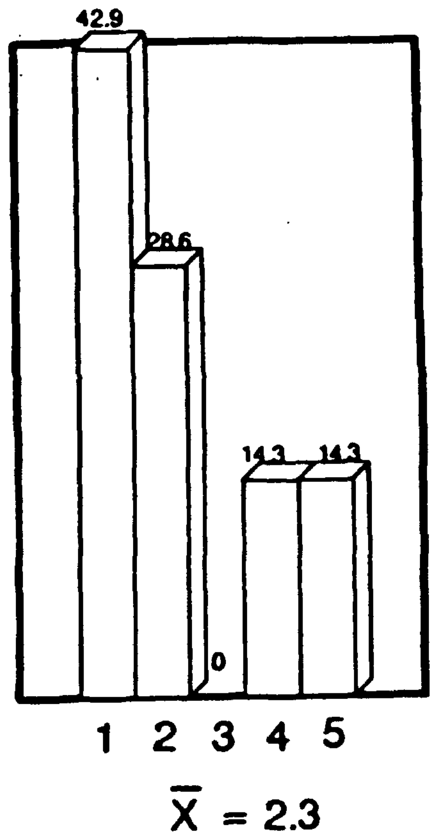


Figure 8. Corps Effectiveness in Adopting Innovative Technologies While Assuring the Construction of Reliable Low-Maintenance Facilities (as Rated by Personnel Surveyed).

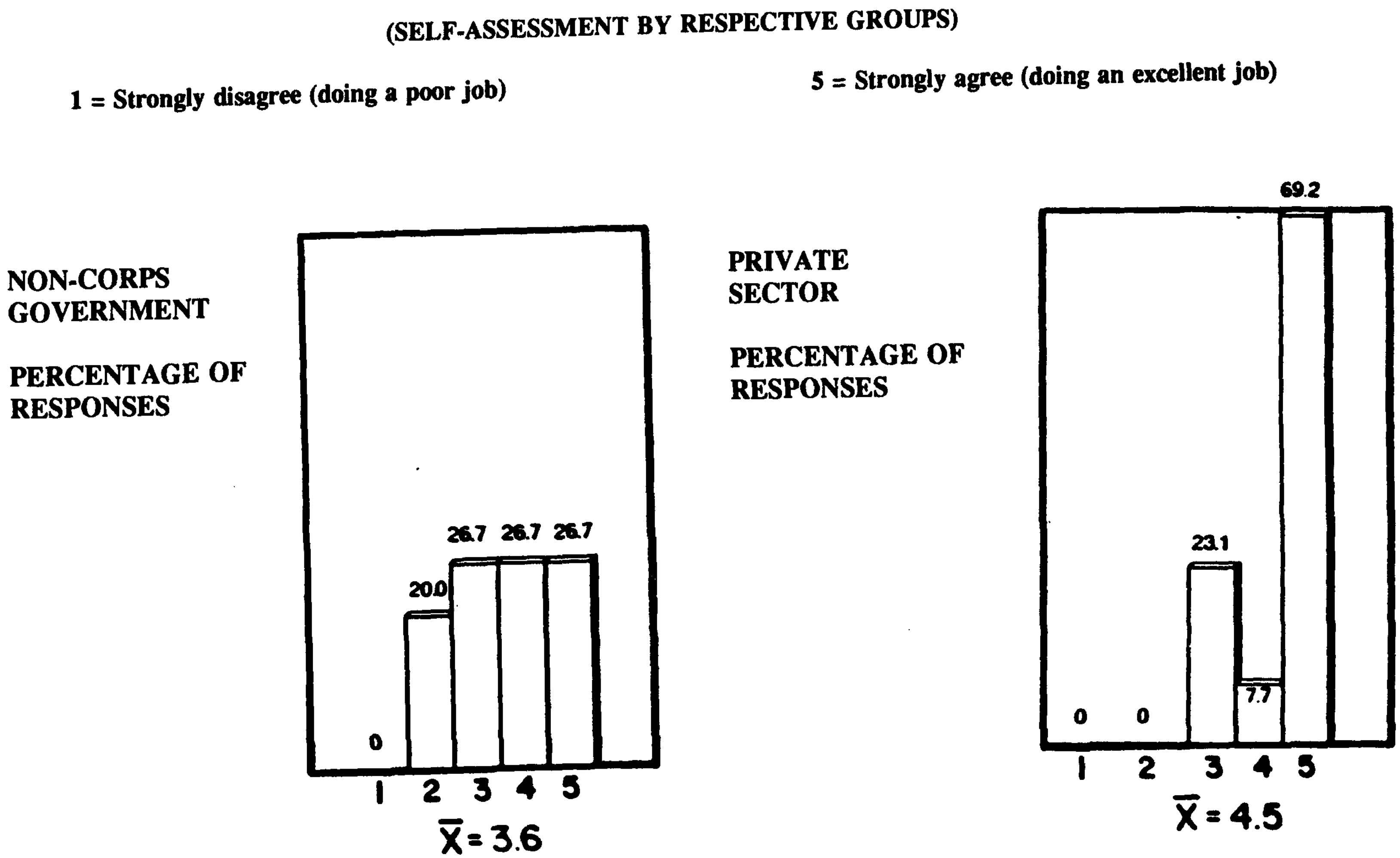


Figure 9. Effectiveness of Non-Corps Government Agencies and Private Industry Organizations in Adopting Innovative Technologies (as Rated by Personnel Surveyed).

Implementation of Innovative Technologies—Two Case Studies

In a further effort to establish a benchmark of performance and identify any additional factors that influence how technologies are adopted, case studies of two different technologies were initiated: passive solar heating and single-ply roofing. These two items were selected because of their levels of development; it was believed that the Corps was ahead of the private sector in passive solar heating but behind in the application of single-ply roofing. The study was performed on contract to maximize objectivity.

It was found that the Corps can be considered about 5 years ahead of the private sector in using and benefitting from passive solar technology.[14] This difference is largely due to the economic situation at the time the study was conducted. With energy costs low, as they were when the study was done, the private sector has little incentive for specifying or further developing this technology. The Corps, on the other hand, has been mandated by Congress to use this technology.

In the area of single-ply roofing applications the Corps was found to be about 10 years behind the private sector.[15] Much of this lag is due to the Corps' conservative approach to new technologies and its reluctance to accept and enforce long-term product warranties.

The purpose of these case studies was to demonstrate that the Corps can be ahead of the private sector in some technologies while behind in others. The findings demonstrate that it would not be easy to accurately quantify, in absolute terms, an overall difference between the Corps and the private sector in terms of their success at adopting innovative technologies. One major inherent difference between the Corps and the private sector deals with the Federal Acquisition Regulations (FARs) and how they govern the Corps procurement practices. The fact that innovative technology developments are often proprietary also limits how and when one specifies a technology for a Corps project.

DEH and Air Force Interviews

DEH and U.S. Air Force (USAF) personnel were interviewed to learn how well the Corps' customers believe the Corps is doing in providing reliable, cost-efficient facilities that employ the latest technology advances. A separate questionnaire was developed for DEH personnel; Air Force personnel were interviewed in person based on the DEH questionnaire. The DEH responses to the four main topic areas were very similar to those obtained from the Corps District and Division offices.

Interview responses by Air Force Engineering Command personnel at three site offices indicated reasonable pleasure with Corps support, with only two areas of concern cited:

- The Air Force Engineering Command is not afraid of the Corps designing anything less than reliable facilities. In fact, the concern is actually one of over-design, which in most cases means higher costs over more conservative designs. Although this may not bear directly on the Corps performance in adopting/incorporating new technologies, it is important to note the Air Force's perception regarding this issue.

- Respondents indicated they felt the Corps is sometimes unresponsive to Air Force requests regarding the incorporation of certain new technologies that the Corps has not yet adopted, or

[14] Charles C. Lozar, *Innovation Adoption Case Studies: Passive Solar and Roofing Technology*, unpublished report, contract DACA88-87-M-1724 (Architects Equities, Inc., Champaign, IL, 14 November 1987).

[15] Charles C. Lozar.

even more common items not normally covered in the Corps' specification/procurement packages (e.g., office furniture).

Vendor Questionnaires

As previously stated, the vendors of new technologies were also included in this study to provide an assessment of the Corps by an external observer familiar with the organization. The vendor questionnaire focuses on how the vendors develop and promote new technologies, with specific references to their dealings with both the public and private sectors. The vendors generally agreed that private-sector organizations were more likely to specify and use a new technology sooner than most public-sector organizations. Overall, the vendor responses support the survey findings and self-assessments pertaining to the organizations' effectiveness in adopting innovative technologies.

Usefulness of Survey Responses in Setting Technology Adoption Benchmark

The best useful benchmark this research can establish for Corps performance in adopting innovative technologies is the Corps' average effectiveness self-rating of 3.0 (as assessed by Engineering Division personnel and shown in Figure 8). This rating is 1.5 points below the private-sector rating of 4.5 shown in Figure 9. This benchmark, however, does not imply that the Corps is some number of years behind private industry. The two case studies cited illustrate why the benchmark has no meaning in that regard; the Corps may be years behind the private sector in some technologies and years ahead in others. This research makes it apparent that to establish a more absolute performance rating would be very difficult (and expensive) if possible at all. Although this study did not establish an absolute benchmark as originally envisioned, the questionnaires revealed important problems to address and, to a significant extent, verified the generally perceived strengths and weaknesses of the current technology adoption process. This research leaves little doubt that the Corps, like other Government agencies, has an inherent adoption lag compared to the private sector in technologies developed in the private sector—especially in proprietary technologies. With this as a given, the job now is to address the identified deficiencies and improve the overall system. With actions to improve the current system (e.g., develop a Corps of Engineers Technology Adoption System [CETAS], as described in the following chapters) and to encourage the organizational perception of being one of the leaders (or key partners) in the development of advanced construction technologies, the Corps will be able to minimize any technology lag, much to the benefit of its customers and the nation.

6 CONCLUSIONS

1. There is no single institutional, Corps-wide approach to the exploration and adoption of innovative building technologies. Although some parts of the overall facility-delivery system address this issue, the system generally functions in an ad hoc manner in this regard, which inhibits efficient technology adoption.

a. No coordinated or cohesive procedures for adopting innovative technologies are organizationally recognized within USACE.

b. The existing ad hoc technology adoption process does not provide a uniform practice or policy for Corps FOAs to consider and adopt innovative technologies. Guidance on the use of innovative technologies is dispersed among many documents. Familiarity with (and interpretation of) this guidance differs among FOAs.

c. The existing ad hoc process does not foster efficient *technology management* because it does not provide personnel with sufficient incentives to encourage the initiation and follow-through on potentially beneficial applications of innovative technologies.

d. A general Five-Step Technology Adoption Process is practiced in many Corps activities, but it is not universally recognized or practiced throughout USACE.

2. The existing ad hoc process does not provide sufficient feedback (e.g., case histories, lessons learned) about field experiences with new technologies to potential Corps users or HQUSACE for effective *technology management.*

3. The existing ad hoc process is nonresponsive to efficient *technology management* for the following reasons:

a. It typically takes too long to draft, review, and publish new or updated engineering and construction guidance documents.

b. It has produced inconsistencies and contradictions between the Corps guide specifications and corresponding engineer manuals and technical manuals. EM and TM content may lag years behind the information in guide specifications.

c. It triggers review and update of CEGS every 3 years, but TMs, EMs, and other engineering guidance documents are not reviewed and updated at the same time, leading to the inconsistencies referred to in the preceding paragraph.

d. It does not include a deliberate and systematic exploration of innovative technologies not already covered by existing guidance documents or practice. It has no effective way to take advantage of actual use of technologies with the process of document revision.

4. The Corps' existing ad hoc technology adoption process does not provide sufficient information on innovative building technologies in a timely fashion. There are no standard format or information content requirements (e.g., performance information, life-cycle cost data, risk factors) for documentation of innovative technologies under consideration. Absence of a cohesive *technology management* approach to documentation in'ibits FOAs and HQUSACE from adopting a new technology. Lack of information is an implicit risk; furthermore, there is always some risk associated with an individual's or organization's

first use of a technology, even one successfully used in other markets. In many cases technical information may reduce the perceived risk, particularly where failure would not pose a life-safety threat. When such information is not readily available to the appropriate USACE and A/E personnel, however, project schedules and conditions tend to inhibit the effort required to obtain it.

5. The existing technology adoption system does not generally accommodate the time, effort, and review procedures required to promote the adoption of new technologies within the constraints of a specific project schedule. As previously mentioned, a project schedule may not allow the time to collect the information needed to lower the perceived risk to an acceptable level. Also, the time needed for higher-level reviews may not be available. Reliance on the status quo is all that is generally allowed. A system of effective *technology management* must address this practical problem by identifying the cases where local office or field personnel are capable of evaluating and approving an innovative technology application without a high-level review (and the delay it causes).

7 RECOMMENDATIONS

Draft preliminary recommendations have been presented to HQUSACE personnel for their reactions and comments at various times during the latter stages of this study. Over the course of this study, the authors have also given several briefings to HQUSACE personnel regarding the study findings. HQUSACE is obviously interested in improving the Corps performance in this area since some efforts in this direction have already arisen from these briefings and draft recommendations. This report represents a final list of recommendations based on the present study.

Recommendations pertaining both to global technology adoption needs and specific needs are made. In some cases the recommended action is very specific; in others, it is more conceptual. Some recommendations will require additional development before they can be implemented. In these cases, the required level of detail exceeded the scope of this general study. Each recommendation is considered to be of about equal importance and all are necessary for the maximum enhancement of the Corps' effectiveness in adopting new building technologies. Some action items will require more time and resources than others, especially those for which further development is necessary. Simultaneous action on several recommendations is feasible and expected; completion of one recommendation is not necessary for the initiation of another.

Overall Technology Adoption Needs

The most important overall need is to establish a cohesive, universal Corps of Engineers Technology Adoption System (CETAS) to identify and adopt new construction and maintenance technologies that will reduce costs for the Army, improve product performance, increase productivity, etc. The success of CETAS will depend on two considerations:

1. An overall institutional environment within which CETAS can exist, including administrative endorsement and continuing support of CETAS, effective applications, appropriate personnel and time considerations, and practical use of CETAS in USACE operations.

2. Effective mechanics of CETAS, including detailed mechanism procedures, the interrelationship of various mechanisms and activities, and information and technology transfer media.

The current technology adoption process has some, but not all, of the necessary elements for CETAS. The following recommendations are made to create a cohesive system from the incomplete ad hoc process currently in place. These recommendations would establish the required elements of an institutional environment and the adoption mechanisms for CETAS to successfully sustain itself as standard USACE practice.

Recommended Action Items

1. Provide a single, clear statement, applicable at all levels of the organization, of CETAS philosophies and goals regarding the application of innovative construction technologies. This statement should serve as an identifiable model for USACE personnel at all policy, management, and technical levels to foster a team approach. The statement should clarify the USACE objective of achieving economic and performance advantages available from new technologies. It should also reinforce USACE quality objectives through pursuit of new technologies in a calculated manner to avoid undue risk. To better

ensure uniform practice, a single unifying Engineering Regulation should be written to provide guidance to FOAs on how to accomplish the stated goals.

2. Establish the Five-Step Technology Adoption Process as the recognized Corps CETAS mechanism for carrying out CETAS policies and philosophies on the adoption of innovative construction and maintenance technologies.

a. While everyone in the organization will not affect every step of the process, or even every component of a given step, the importance of each person's contribution to the five-step process must not be underrated. Success on an institutional level will depend on a successful team effort, with everyone recognizing their potential contribution and acting accordingly. For this to happen, the five-step process must be introduced into everyday thinking of the Corps family, especially technical and professional personnel involved in any phase of project design and specification. Everyone must become aware of the philosophies and components of the five-step process and understand how they may best support the process in their everyday activities.

b. Establish a single, identifiable means of coordination among all HQUSACE Engineering disciplines, the national teams, and USACE laboratories to promote and direct CETAS. The Corps of Engineers Advanced Construction Technology Team (CENACTT) would be a logical candidate to assume a technology advancement liaison and steering capability, as this relates directly to its charter. With the necessary authorization and authority within USACE, and input from the other national teams, HQUSACE Engineering and Construction divisions, labs, and TCXs, CENACTT would act as the promoter and manager of this process.

3. Enhance the incentives for initiating and following through on the application of new technologies in support of CETAS. Rewards are needed for individuals who go "above and beyond" what is considered reasonable effort within project conditions. Also, institutionally imposed disincentives should be removed to encourage new levels of individual professionalism and initiative.

a. Encourage the effective use of technical information by making the necessary adjustments in daily practice. Allow for the routine review of technical information in the day-to-day activities and responsibilities of Corps personnel.

b. Simplify the review and approval process for initiatives to use new building technologies not included in current CEGS. To make sure any such simplifications have the intended effect at the working level, a follow-up survey including this topic is recommended for sometime during the next 3 to 5 years.

Identifying, creating, and administering the appropriate incentives is a complex issue and must be explored in detail before any attempt at implementation. Such a program must be designed for *concrete results* and must provide *opportunities at every level of the organization.*

4. Actively manage CETAS procedures for drafting, reviewing, and publishing updated engineering and construction guidance documents (CEGS, EMs, TMs, Engineer Technical Letters (ETLs), etc.) for use throughout the Corps. CETAS procedures should treat these documents as a system of documents, and take into account differences in particular media and the various levels of jurisdiction. Publication, review, and update need to be coordinated so one document does not contradict or unnecessarily restrict the guidance presented in another.

a. Initiate a comprehensive *project management* approach to the development and maintenance of *all* relevant engineering and construction guidance documents and other sources of technical expertise.

HQUSACE personnel have begun efforts to streamline and expedite the CEGS updating process. However, these improvements may not be far-reaching enough. Project managers would use the CEGS update triggers to also initiate the appropriate revisions of TMs, EMs, and other associated documents. Where these other documents are outside USACE jurisdiction or follow different revision cycles, explicit guidance should be included in the USACE document on how these externally published documents are to be observed.

b. Assign the project managers the prime responsibility for developing a process to reduce the technology gap that currently exists between the CEGS and the corresponding manuals. *This is the most important improvement needed in the area of guidance documentation.*

c. Ensure that new technologies originating from all sources are given prompt and appropriate consideration. Draft design and construction guidance (CEGS, EMs, etc.) should be developed and sent to Huntsville Division for further action immediately upon successful demonstration of new technologies in FEAP, the T^3B program, and other demonstrations.

d. Use additional vehicles (e.g., new publications, training programs) for successful dissemination of new building technologies. Some new media arising from this recommendation were launched even before this report was finished. One such publication, the *Engineering Improvement Recommendation System (EIRS) Bulletin*, serves the dual purpose of introducing a technological improvement before its publication in applicable technical documents as well as providing a channel for feedback from field experiences. Other technology transfer media that could play an important part are the FEAP flyers and national team bulletins and newsletters. Where appropriate, introduce new technologies in USACE training as soon as practicable, use training provided through private and industry sources, strategic support centers, and TCXs.

5. Establish a CETAS procedure for acquiring and disseminating (i.e., managing) complete and accurate information on new technologies not covered in existing Corps guidance or documentation. This information should be applicable and usable within project-specific requirements and conditions. Complete, credible information will promote appropriate applications of innovative technology, prevent inappropriate applications, increase confidence in satisfactory performance, and reduce the overall risk perceived for a new technology. Providing clear and timely information is imperative so it is useful in the context of project-specific schedules and conditions.

a. A very important part of establishing a cohesive technology adoption system may be Corps support for and participation in the Advanced Construction Technology System (ACTS), an information service currently being developed by the Construction Industry Institute (CII) and USACERL under the USACE Fiscal Year (FY) 89 Construction Productivity Advancement Research (CPAR) program.

b. Support the development and adoption of new technologies through the CPAR program. CPAR activities by USACE laboratory and FOA personnel should include acquisition and dissemination of information on the technologies developed through the program. CPAR provides an excellent opportunity to cooperatively develop (with university and private-sector partners) innovative construction and maintenance technologies that can benefit both the Corps and the construction industry.

c. In some cases the existing information base may not be sufficient, or the validity of performance claims may be questionable. In these situations, evaluation by one of the Corps R&D laboratories may be warranted, especially if the technology offers high potential benefits. The Corps R&D laboratories' mission should, therefore, include the responsibility to investigate promising new technologies that would otherwise be missed in the R&D effort. (This mission would not include evaluation or testing of an item from a new vendor if that item represents an already established level of technology used by the Corps).

6. Introduce a *technology management* approach, specifically and directly in support of CETAS, to acquiring and disseminating feedback from field experiences with new technologies. This would involve consolidating the existing feedback channels, both formal and informal, and expanding them into additional areas. Both successes and failures (i.e., failure to perform up to expectations) should be communicated; detailed communication on failures is quite important. Sometimes only a minor design or application change is needed to transform a technology failure into a success. Also, the failure of a technology for one particular application does not necessarily mean that the technology will not succeed in another application with a different set of circumstances. In general, an effective feedback process would do much to expedite the widespread use of successful new technologies and add to the database of performance expectations and maintenance requirements. Such information must be readily available to project management and design personnel to be useful on a project-specific basis.

Maximize the use of information available from field and construction experiences, and disseminate it to all appropriate USACE offices. Encourage the use of Engineer Form 3078 through appropriate incentives or inclusion in employee performance standards. Include issues other than deficiency reports on 3078s (e.g., experience with a new technology, recommended applications, sources of information). The scope of Engineer Form 3078 should be expanded to include civil works as well as military activities. Prevent any negative impacts on personnel who report negative experiences or failures if such occurrences were not the result of negligence or an obvious misuse of technology.

7. At an appropriate time in the future, perform follow-up work to evaluate the effectiveness of any actions initiated as a result of this study and recommend further improvements.

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ACRONYMS

ACTS	Advanced Construction Technology System
A/E	architect/engineer
AFR	Air Force Regulation
AR	Army Regulation
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BTFE	Building Technology Forecast and Evaluation
CEGS	Corps of Engineers Guide Specifications
CENACTT	Corps of Engineers National Advanced Construction Technology Team
CENET	Corps of Engineers National Energy Team
CETAP	Corps of Engineers Technology Adoption Process
CETAS	Corps of Engineers Technology Adoption System
CII	Construction Industry Institute
CPAR	Construction Productivity Advancement Research
CRC	Construction Research Center
CW	civil works
DA	Department of the Army
DCFP	Design Criteria Feedback Program
DEH	Directorate of Engineering and Housing
DOD	U.S. Department of Defense
EC	Engineer Circular
EIRS	Engineer Improvement Recommendation System
EM	Engineering Manual

ACRONYMS (Cont'd)

EP	Engineer Pamphlet
ER	Engineer Regulation
ETL	Engineer Technical Letter
FARs	Federal Acquisition Regulations
FE	facilities engineer
FEAP	Facilities Engineering Program
FOA	field operating activity
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HQUSAF	Headquarters, U.S. Air Force
M&R	maintenance and repair
MCA	Military Construction, Army
NAVFAC	Naval Facilities Engineering Command
OCE	Office of the Chief of Engineers
O&M	operations and maintenance
PCI	Post Completion Inspection
POC	point of contact
R&D	research and development
RDTE	Research, Development, Test, and Evaluation
SOP	standing operating procedure
T^3B	Technology Transfer Test Bed
TM	Technical Manual
TCX	Technical Centers of Expertise

ACRONYMS (Cont'd)

USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory
USACRREL	U.S. Army Cold Regions Research and Engineering Laboratory
USAETL	U.S. Army Engineer Topographic Laboratory
USAF	U.S. Air Force
USAWES	U.S. Army Waterways Experiment Station
VE	Value Engineering
VETRIEVAL	Value Engineering Retrieval

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