



Technical Report CADD-96-1
August 1996

**Tri-Service CADD/GIS
Technology Center**

Estimating Costs for Architect-Engineer (A-E) Computer-Aided Design and Drafting (CADD) Services

Approved For Public Release; Distribution Is Unlimited

Published by U.S. Army Engineer Waterways Experiment Station

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.



PRINTED ON RECYCLED PAPER

Technical Report CADD-96-1
August 1996

Estimating Costs for Architect-Engineer (A-E) Computer-Aided Design and Drafting (CADD) Services

by Bobby G. Carpenter

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

John F. Hill, Michael P. Ingardia
Systems Management Consultants, Inc.
14109 Woodward, P.O. Box 23145
Overland Park, KS 66223

Final report

Approved for public release; distribution is unlimited

Waterways Experiment Station Cataloging-in-Publication Data

Carpenter, Bobby G.

Estimating costs for architect-engineer (A-E) computer-aided design and drafting (CADD) services / by Bobby G. Carpenter, John F. Hill, Michael P. Ingardia.

47 p. : ill. ; 28 cm. — (Technical report ; CADD-96-1)

Includes bibliographical references.

1. CAD/CAM systems — Costs. 2. Design — Computer simulation — Costs. 3. Computer-aided engineering. 4. Architectural design — Computer simulation — Costs. I. Hill, John F. (John Frank), 1946- II. Ingardia, Michael P. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; CADD-96-1.
TA7 W34 no.CADD-96-1

Contents

1 — Introduction	1	File security	13
Purpose	1	Technical obsolescence of	
Applicability	1	electronic files	14
Background	1	Natural deterioration of	
Report Development Process	2	electronic files	15
Research	2	3 — CADD Services Cost Estimating	
Interviews with Government		Methods	16
representatives	2	Hourly Rate	16
Interviews with A-E design		Firm-Wide Overhead	16
contractors	2	Current Practice	17
Review of applicable		Estimating Costs for CADD	
publications	3	Services	17
A-E Contracting Process	3	Validity of old rules of thumb	18
2 — CADD Services Cost Factors	5	Changes in overhead costs and	
Firm-Wide Costs	5	payroll multipliers	20
Project-Specific Costs	6	Trends	22
CADD Standards	7	4 — Recommendations	23
Typical practice	7	Payment for CADD Services	23
Tri-Service A/E/C CADD		Suggested Estimating Procedures	23
standards	9	The CADD Standard	23
Planning	9	Government-furnished	
Government-Furnished Material	9	materials	24
Procedures	10	Drawings the Contractor will	
Acceptance of Electronic Files	10	deliver to the Government	24
As-Built Drawings	10	Interim submittals	25
Professional Liability	10	Final delivery	25
Storage/Archiving	10	As-built drawings	25
Electronic CADD Media		Archiving	25
Deliverables	11	Suggestions for Reducing CADD	
Uses of delivered CADD files	12	Costs	26
Handling of the electronic		Project team communication	26
CADD files received by the		Ultimate file use	26
Government client	13		

Delivery requirements in contract language	26
Clear, uniform, and easy to understand CADD Standard	27
Government-finished electronic data	27
Pework project meeting	28
Electronic file testing	29
Interim electronic format submittals	29
Professional liability	29

Checklist and Sample Spreadsheet for Preparing Estimates	29
References	30
Appendix A: Glossary	A1
Appendix B: Check List	B1
Appendix C: Sample Spreadsheet	C1

SF 298

1 Introduction

Purpose

The purpose of this report is to provide guidance and recommended procedures for estimating the costs associated with the preparation of design drawings by architect-engineer (A-E) contractors using computer-aided design and drafting (CADD) technology. The report addresses the following key areas:

- a.* The costs associated with the development of CADD products.
- b.* How CADD costs are typically addressed in an A-E contract.
- c.* Current practices for estimating the costs associated with the development of CADD products.
- d.* The validity of using old rules of thumb for estimating A-E CADD design costs.
- e.* The process of verifying A-E CADD cost estimates.
- f.* A consistent approach to making cost estimates and suggested ways to improve procedures and reduce A-E CADD costs will be proposed.

Applicability

This report is applicable to all Department of Defense (DoD) contracting, project management, and technical design personnel involved in the acquisition of the services of A-E contractors to prepare and deliver CADD-generated design products. The report would also be useful to all A-E contractors who are involved with the development of CADD-generated design products for DoD organizations.

Background

Most current Government design projects require A-E contractors to use CADD systems in performing their work and to deliver electronic CADD files as part of their deliverables. Estimating design costs for such projects has posed problems both to the A-E design contractors and to the Government project managers.

Government project managers and Contracting Officers are often uncertain about how to estimate CADD costs for design projects. They do not follow a consistent methodology in preparing their initial project cost estimates. As a result, cost estimates for the preparation of CADD generated products made within a single agency usually vary a great deal, with some landing below the actual resulting costs, and others landing beyond.

A-E design contractors also seem to be uncertain about how to estimate their CADD costs. Differences between the operations of different designers and differences within a single contracting firm from one project to the next have resulted in varied and seemingly inconsistent proposals to the Government.

Because of these inconsistencies, it is often difficult for Government project managers and Contracting Officers to evaluate the proposals they receive and to compare them with one another. They have difficulty determining whether the costs for CADD work included in proposals are reasonable, insufficient, or excessive.

Report Development Process

Research

The research, interviews, and basic preparation of this report was accomplished by Systems Management Consultants, Inc. (SMC), 14109 Woodward, P.O. Box 23145, Overland Park, Kansas 66223, through Contract No. DACW39-94-M-6453 with the Tri-Service CADD/Geographic Information System (GIS) Technology Center, U.S. Army Engineer Waterways Experiment Station (WES), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

Interviews with Government representatives

SMC representatives, Messrs. Michael P. Ingardia, P.E., and John F. Hill, American Institute of Architects (A.I.A.), interviewed representatives of the Tri-Service Technology Center (TSTC); U.S. Army Engineer District (USAED), Vicksburg; USAED, Mobile; USAED, Little Rock; and USAED, Kansas City.

Discussions during the interviews ranged over many subjects, including:

- a. Types of design projects contracted to A-E's at each office.
- b. Current requirements for A-E CADD products and electronic CADD file deliverables.
- c. The CADD standards for required A-E electronic CADD file deliverables.
- d. The procedures for implementing A-E electronic CADD file deliverable requirements.
- e. The procedures for handling the A-E's electronic CADD file deliverables.
- f. The Government representative's recommendations for estimating costs for development of CADD products by A-E contractors.

Interviews with A-E design contractors

SMC representatives Ingardia and Hill interviewed representatives of Michael Baker, Jr., Inc., Jackson, MS, and Sverdrup Civil, Inc., St. Louis, MO.

Discussions during these meetings touched on:

- a. Local project experiences with U.S. Army Corps of Engineers (USACE) and other DoD and Government clients.
- b. A-E design contractors organization of their own CADD operations.

- c. CADD standards, libraries, menu structures, etc., used by A-E design contractors.
- d. Experiences in providing CADD products to meet different client CADD standards and requirements.
- e. Project CADD costs and cost estimating procedures used by the A-E design contractors.
- f. Procedures for performing project CADD work to the required CADD standard.
- g. Problems encountered during the development of CADD products.

Review of applicable publications

SMC representatives Ingardia and Hill reviewed a number of related publications, which included:

- a. Draft Tri-Service A-E CADD Deliverables Standards. (TSTC in preparation).
- b. Draft Tri-Service Architectural, Engineering, and Construction (A/E/C) CADD Standards, Report 1, Standards Manual. (TSTC in preparation).
- c. Design Services Fee Structure Survey. (Practice Management Associates, Ltd. 1994a).
- d. CADD Applications and User Survey. (Practice Management Associates, Ltd. 1994b).
- e. CADD Risk Management for Design Firms, (Systems Management Consultants 1993).
- f. Contracting for CADD Work: A Guide for Design Professionals, (Systems Management Consultants 1994).

A-E Contracting Process

To acquire the services of A-E firms, Government agencies are required to follow the procedures defined in the *Federal Acquisition Regulations (FAR's), Part 36*. Additional requirements for the Department of Defense (DoD) are included in Part 236 of the DoD FAR supplement (DFAR's). In 1972, Congress enacted Public Law 92-592 (called Brooks Bill) which defines A-E services, states how prospective contract awards are to be announced, and clarifies the procedures for selecting A-E's and negotiating their contracts.

There are two broad categories of contract types used by the Government, fixed-price and cost-reimbursement. Several variations of both contract types are available for use by Government agencies.

The cost-reimbursement contract provides for reimbursing the contractor for all (or, on occasion, a portion of) allowable and allocable costs incurred in the performance of the contract to the extent specified in the contract. The cost-reimbursement contract includes an estimate of total cost for the purpose of obligating funds and establishing a cost ceiling which the contractor may not exceed without prior approval of the Government Contracting Officer. The contractor agrees, but does not guarantee, to do his best to complete the specified product within the cost ceiling.

The fixed-price contract includes a price ceiling limiting the financial obligation of the Government to the contractor for satisfactory completion of the contract, and the contractor guarantees completion of the specified product. A-E design contracts are typically either the negotiated firm fixed-price or the indefinite delivery order type.

In the negotiated firm fixed-price contract, the A-E contractor agrees to accept all risks and provide the specified product for the stated fixed price. The A-E assumes full responsibility in the form of profits or losses,

for all costs under or over the firm fixed price, which are incurred during the process of completing the work specified under the contract. No adjustment in the price will be made unless the contract scope of work is changed by the Government and the contract is modified by the Government Contracting Officer.

Indefinite delivery order contracts are used where there will be a recurring demand for certain types of design work, but the timing and/or full extent of the demand are not certain. In other words, the general types of design work that will be required are known, but the full scope and the specific project details are not known at the time of contract award. The contract establishes fixed hourly rates for the disciplines of design personnel and other design related items which are required. The contract also contains detailed administrative and technical contract provisions for the development and delivery of the types of design work to be accomplished under the contract. A maximum cost and time limit, which cannot be exceeded, are included in the contract. The Government

assigns work to the A-E contractor through the award of individual delivery orders.

U.S. Army Corps of Engineers guidance and regulations which are applicable to A-E contracting include:

- . Engineer Circular, EC 715-1-87, Negotiation of Architect-Engineer Services.
- . Engineer Regulation, ER 715-1-15, Time Standards for Architect-Engineer Contracts
- . Engineer Regulation, ER-715-1-16, Selection of Firms for Architect-Engineer Contracts.

Guidance and recommended procedures for the preparation of Commerce Business Daily (CBD) announcements and contract provisions for use in acquiring the services of A-E firms to prepare and deliver CADD generated products are included in Part 1.1 of the Tri-Service Standards, entitled A-E CADD Deliverables Standards..

2 CADD Services Cost Factors

Using a CADD system to produce project drawings may cost an A-E design contractor less than preparing the drawings by hand, but at times could cost more. In either case, using a CADD system to produce project drawings represents a definite cost. The A-E design contractor's costs to produce CADD drawings fall into two general categories, firm-wide and project-specific costs.

Firm-Wide Costs

These are the A-E design contractor's costs which can most fairly be allocated over the contractor's entire operation. These costs include:

- a. *Acquiring hardware and software.* A sizeable initial investment is required to purchase and install the CADD computer hardware and software. The type and quantity of computer hardware depend upon the number of employees using the CADD system (i.e., hardware and software) and the type of CADD work to be performed. Computer hardware may consist of workstations with a UNIX operating system, or stand-alone or networked personal computers (PC's) with MS-DOS, Windows (e.g., 3.1 or 95), or Windows NT operating system, or combinations of all. Basic CADD software (e.g., AutoCAD (Autodesk) and MicroStation (Bentley)) provides fundamental drafting and design capabilities. More specialized types of design work may require the use of CADD application software. The CADD application software operates "on-top-of," or in conjunction with, the basic CADD software package to perform a specific function. Additional hardware and software is required to perform other functions such as scanning, digitizing, plotting, and communications. Database, spreadsheet, word processing, and document management software may also be needed.
- b. *Upgrading and maintaining the system.* Upgrades of CADD, database, operating system, and other support software are developed periodically by the product manufacturers. Faster and more productive hardware is also developed each year. Typically, software is upgraded annually. Because of the cost, hardware is usually upgraded incrementally and not all at one time.
- c. *Administering and managing the system.* A trained operator or technician is required to manage the operation of workstations and networked PC's. Typical duties include loading and configuring the software, performing component upgrades of the hardware, and performing routine backup and archiving operations.
- d. *Supplies and other operating costs.* Supplies (e.g., paper, plotting film,

replacement cartridges, diskettes, etc.) are required. recover during the course of the project. These costs include:

- e. *Developing procedures and local software tools such as menus, macros, user commands, and libraries.* The development of Standard Operating Procedures (SOP); customized menus; macros; user commands; and font, line type/style, symbol, and detail libraries will have an initial cost, but will enhance efficiency and productivity in the long run.
- f. *Maintaining and upgrading procedures and local software tools.* The identification and development of better and more efficient procedures and local software tools will have an initial cost but will enhance efficiency and productivity in the long run. Local software tools such as custom menus, macros, user commands, and libraries must be upgraded whenever the software is upgraded.
- g. *Training CADD staff when the system is first acquired.* All employees who will be using the CADD system must receive training in, at least the fundamental operations of, the CADD and appurtenant software.
- h. *Maintaining the skills of the CADD staff through ongoing professional development.* Update training is necessary for the staff to stay abreast of new developments in the CADD software and to become more proficient in the use of the CADD software.

Project-Specific Costs

Project-specific costs can be allocated to the work performed on a specific project. The costs represent tasks and activities that may or may not be specifically included in a project's scope of work but which must be performed in order to complete the project. They do represent costs to the contractor which the contractor will try to

- a. *Developing a detailed plan to include the schedule, staffing, and costs necessary to produce the CADD products.* This is developed after a clear understanding of the project scope of work has been achieved. Additional software (e.g., CADD application software), hardware, and/or employees/consultants might be required to satisfy the contract requirements. The schedule included in the project scope of work may require overtime, or variations in work schedules (e.g., working in shifts if the quantity of hardware and software is insufficient).
- b. *Preparing to produce the CADD work:* If the client requires the use of a new CADD specification/standard, the following costs may be incurred. This should be an initial one-time "start-up" type cost.
 - (1) Evaluating the client's CADD specification/standard.
 - (2) Negotiating any necessary modifications to the CADD specification/standard with the client.
 - (3) Modifying the firm's standard production procedures as required to perform the project work. Such modifications might include writing new menus, macros, user commands, or developing new library material.
 - (4) Training the CADD staff to use the modified tools or procedures.
- c. *Producing CADD drawings and products for the project.*
 - (1) Receiving electronic data and other material from the client or from other outside parties and readying the material for use. Steps in this process

might include receiving the material, importing it into the contractor's own CADD system, reviewing its contents, and modifying the material if required.

- (2) Running any required design calculations with the appropriate design software and importing this information into the CADD drawing system.
- (3) Preparing the CADD drawings.
- (4) Preparing the document packages for the required CADD submittals.
- (5) Receiving the client's review comments and making necessary modifications to the work.
- (6) Costs for supplies, materials, and services such as plotting and printing.

CADD Standards

The CADD standards that A-E contractors are required to follow in producing their CADD products may have an impact on the costs and the amount of time it takes to produce project drawings. If there is no required CADD standard, the A-E contractor will follow his firm's preestablished procedures and standards in performing the project CADD work.

Working for a client that has a CADD Standard different from the one currently being used changes the A-E design contractor's picture significantly. Preparing a Contractor's CADD staff to use the client's CADD standard is like retooling a factory to make a special production run.

Even when the client's CADD standard is no more complex than the Contractor's normal standard, the contractor must devote significant effort to evaluating the client's CADD standard and modifying his own normal procedures to let

his staff work to the client's standard. The Contractor's CADD staff must learn the new procedures and then pass through a learning curve as they become accustomed to the new procedures and regain their normal level of productivity. If the project is of small scale or short duration, the Contractor's CADD staff may not regain its previous level of productivity.

Typical practice

A typical A-E design contractor may be required to prepare CADD products to a number of different CADD standards for different clients and on different projects. Sometimes a client's contract contains no specific requirement and the contractor can follow his firm's own in-house CADD standard, maximizing the productivity of his CADD staff. More frequently, though, the Contractor's clients will have their own CADD standards and will require the contractor to follow them.

Some A-E design contractors do most of their work for a single client like a single large company, a local government organization, a state government organization, or a Federal Government organization. Some of these single clients still do not require their A-E design contractors to submit electronic files, and some who do have a CADD file delivery requirement leave the CADD standard up to the contractor. For example, the staff at the Michael Baker, Jr., Inc., office in Jackson, MS, reported that they do a substantial amount of work for the Mississippi State Department of Transportation and that this client does not yet require the submittal of CADD files. Few private clients adopt the same CADD standard. The CADD standards of public clients tend to vary by jurisdiction.

Many national organizations and client agencies have adopted national CADD standards that are nominally uniform and consistent, but local practice varies greatly. Contractors report encountering significant variations within a single business or agency. Whatever the official national

policy may be, there are likely to be many local differences.

SMC's interviews with the selected A-E design contractor and Government personnel indicate these differences. Currently, CADD standards may vary significantly between the district offices of the Corps of Engineers, as well as among the individual offices of the other DoD agencies. EM 1110-1-1807, "Standards Manual for U.S. Army Corps of Engineers Computer-Aided Design and Drafting (CADD) Systems" (Headquarters, Department of the Army 1990), was published to provide a standard format for the development of CADD products within the USACE. Some of the USAED's have developed their own customized CADD standards which use a combination of parts of EM 1110-1-1807, some pre-CADD, hand-drafting standards, and locally developed CADD standards. Some may also use CADD standards which were originally developed in other districts (for example, the USAED, Kansas City, staff reported that portions of their standard carry over from an old USAED, St. Louis, standard that existed when the USAED, Kansas City, received its first CADD system).

Interviews indicated that there have been variations in the requirements to use a specific CADD standard within each District. Project Managers seem to have considerable latitude in how they implement CADD standards. In some cases, a Project Manager takes a consistent approach to CADD standards which shows in all of that Project Manager's projects. In some cases, the Project Manager takes a flexible approach and makes decisions on project CADD standards based on the nature of the project and the capability or capacity of the A-E design contractor.

Project CADD standards have typically tended to be more strict in situations when:

- a. Projects are large and last over a long period of time.

- b. Other parties will be using the electronic CADD files directly.
- c. Projects are being designed by large corporate A-E design contractors who have significant CADD capabilities.

Project CADD standards have typically tended to be less strict in situations when:

- a. Projects are small or short term.
- b. Projects involve repairs, renovation, and remodeling.
- c. Projects are designed by small local consulting firms.
- d. Projects will go directly from design to construction and nobody on the team really knows how the electronic CADD files will be used.

In some cases, there have been no CADD delivery requirements at all, or the Contractors have been permitted to submit electronic files in the formats of CADD systems other than the one that is the Corps of Engineers' official standard. In these cases, the Project Manager's priority was on the technical accuracy of the design information contained in the electronic CADD files that the contractor delivers.

Tri-Service A/E/C CADD standards

The Tri-Service CADD/GIS Technology Center is drafting CADD standards for use by all Army, Navy, and Air Force (or Tri-Service) components. A portion of this standard has already been released for review in draft form under the name *Tri-Service Architectural, Engineering, and Construction (A/E/C) Computer-Aided Design and Drafting (CADD) Standards, Report 1, Standards Manual* (TSTC in preparation). The draft document includes material on required electronic file parameters and on file layering. The draft standard provides for Tri-Service components receiving electronic files

in either Intergraph MicroStation or Autodesk AutoCAD format.

The Tri-Service A/E/C CADD Standard is comprehensive, and its initial implementation will result in short-term Government and A-E contractor “start-up” costs. Once implemented, however, a consistent Tri-Service A/E/C CADD Standard will save costs for both the A-E contractor and for the Government client agency that hires the contractor, simply by reducing the number of standards that the contractor must learn. Reducing the number of different CADD standards that a contractor must meet working on different projects reduces that contractor's cost.

Fewer CADD standards to meet means fewer CADD standards to evaluate and fewer CADD standards to tool up for and follow. The A-E design contractor's CADD staff will soon become proficient in using the CADD standard and will be able to achieve a higher level of productivity and quality.

The idea of a single CADD standard to be uniformly implemented by all the services has a great deal of appeal. A single CADD standard that would be used by all Government elements is even more appealing.

Planning

CADD costs can be reduced if the Government Project Manager and the appropriate Government technical personnel take time to discuss the CADD requirements with the contractor in detail and answer the A-E design contractor's questions before the project work begins. This can assure that all parties understand what is expected, thereby reducing false starts and the need for expensive backtracking. Exchanging sample files before project work begins can ensure that the Project Manager's agency and the end user will be able to use the files submitted at the end of the project as expected without expensive and time-consuming modification.

Government-Furnished Material

CADD costs can be reduced if the Government will provide the contractor with seed files/prototype drawings, symbol and detail cell libraries, font and line type/ style libraries, and workspaces configured in accordance with the Government's CADD standard. The less the A-E design contractor must develop from scratch, the lower his proposal and costs to the Government will be.

Government-provided information on existing conditions (e.g., as-built drawings) can also affect project CADD costs. This material can reduce or increase project CADD costs, depending on the quality of the material and how easily it can be used. Typically, the more information and data the Government can provide the A-E contractor, the lower the A-E costs to the Government will be.

Procedures

Complex project procedures will increase CADD costs. A project schedule that is unclear or is not observed can lead to delays, false starts, and frustration. Interim submittals that are required to include more than the Project Manager will require (for example, a requirement for interim submittals of CADD files when the Project Manager intends to review the submittal from blueprints) add to the Contractor's efforts and to his costs.

Acceptance of Electronic Files

The A-E design contractor's CADD costs increase if he is required to maintain and support the project CADD files for an extended period after making the last submittal while waiting for final acceptance of the design and files. If the Contractor knows that acceptance of these electronic files will be delayed for a significant

time after submittal, his proposal will include money to cover his potential cost exposure.

As-Built Drawings

The A-E design contractor's CADD costs increase if he is required to develop electronic as-built drawings at the end of project construction. However, electronic files of as-built drawings will probably be more useful than design or bid drawings to the end user in his ongoing use of the facility. Paying the Contractor to develop as-built drawings may be a good investment, since the Contractor who already knows his way around the project CADD files can update the bid drawings more efficiently than anyone else. An agreement to develop as-built drawings should be specifically written into the designer's contract and should clearly assign responsibility for gathering as-built information at the job site and conveying it to the Contractor.

Professional Liability

The A-E design contractor's CADD costs increase if he is required to assume more than the customary professional liability. CADD costs do not increase if the Contractor is assured that the electronic files he delivers are received, reviewed, and accepted in a timely manner by the Government and then managed and handled in a manner that protect the Contractor from additional professional liability.

Storage/Archiving

The A-E design contractor's CADD costs increase if he is required to store or archive the project CADD files after project completion. Such a requirement means that the Contractor must initially prepare the files for storage in the archive and document the archived material. He must then store the files in a protected environment, maintain them by recopying them annually, and upgrade them to track changes in

hardware, software, and operating systems. A Contractor who is faced with a requirement to store files for extended periods after the end of the project will include these costs in his proposal.

Electronic CADD Media Deliverables

Why are A-E contractors required to deliver their designs in CADD electronic media format? What does the Government intend to do with the design data it receives from the Contractors? The interviews indicated that many contractor and Government staff have not fully understood the answers to these questions.

In some instances, such as mapping and survey work, the electronic files the Contractor delivers are delivered in turn to the end users who begin to use them almost immediately. In these cases, the purpose of the requirement for electronic file delivery is clear, and there is little argument about the need to make the electronic delivery or follow the client's CADD Standard for the work.

In the past, Project Managers for civil and architectural projects have typically had different priorities. They are primarily concerned with the technical correctness and accuracy of the drawings they receive and if they clearly show how to construct the project being designed. They may tend to be less concerned about the electronic CADD files the contractor delivers, particularly if they do not understand how the files will be used in the future.

The interviews indicated that the primary goal of the Government Project Managers managing civil and architectural design work has been to receive drawings from the A-E design contractors that are technically correct and that will permit them to get the design project constructed on time and within budget. They may not find that the CADD files are very useful to them in their own work, and they may not have a clear understanding about how the electronic files will be used in the future.

The interviewed Government Project Managers indicated that they are under pressure to complete their projects on time, within budget, and within their own internal time budget. They must carefully monitor their time and cannot spend in-appropriate amounts of time on anything that does not visibly contribute to what they see as their main goal — getting the project completed or constructed.

For such a Project Manager, the ideal CADD Standard is simple and self-explanatory. It is a packet of documents, or preferably electronic files, that the Project Manager can pass directly to the A-E design contractor without having to discuss it in detail with the Contractor, or even absorb it himself. He wants the Contractor to absorb the information on his own and complete the project design work in an expeditious manner without requiring a lot of guidance from the Government Project Manager or the Government's technical personnel.

The interviews indicated that at the end of the project design, the A-E design contractor typically delivers the reproducible project drawings and electronic CADD files to the Government Project Manager. For a construction project, the project drawings are reproduced into sets of half-size or full-size prints for distribution to potential bidders. The electronic CADD files may be placed in storage (in a desk drawer, file cabinet, or someplace more secure) where they remain unless they are needed for developing amendments, modifications, or as-builts to the project drawings. The electronic files may not always be checked for conformance to the Government's requirements.

Uses of the delivered CADD files

How does the Government plan to use the electronic CADD files that the Contractor is required to deliver? There are many possible uses for this information. Some of the obvious desired uses include:

- a. Uses by the Government Design and Construction Office:

- (1) Preparing contract modifications.
 - (2) Staking out the job site during construction.
 - (3) Preparing as-built drawings at the end of construction.
 - (4) Preparing drawings for future phases of construction.
 - (5) Passing to other specialty contractors for postconstruction contracts such as landscaping or signage.
 - (6) Long-term archiving.
- b. Uses by the project end user, Government Operations/Maintenance, or Facility Management Officer:
 - (1) Space planning use by the end user.
 - (2) Furniture planning.
 - (3) Ongoing facility management.
 - (4) Planning documents for future work on the facility.
 - (5) Long-term archive.
 - (6) Master Planning.
 - (7) Development of GIS maps.

The project team (A-E and Government) should know how the electronic CADD files will be used by the Government in the future. This determination should be made by the Government prior to initiation of the A-E contract. This knowledge will provide the project team with a sense of purpose for the electronic CADD file delivery requirement, provide more incentive to coordinate the development of the CADD products more carefully, and ensure that the electronic CADD files will be compatible with Government's CADD, GIS, or Computer-Aided

Facilities Management (CAFM) Systems. With this incentive, the Government's Project Managers will be more likely to:

- a. Review the required CADD Standard before the drawing work begins and decide how the standard should be applied to the project work.
- b. Decide how the CADD Standard will be implemented to meet the project's needs.
- c. Exchange test files with the A-E design contractor before the drawing work is underway and verify that the Contractor's files can be read and that they will serve the desired purpose.
- d. Review the files that the contractor delivers with the project submittals to verify the technical accuracy of the design information and to verify that the files themselves meet the CADD Standard.
- e. Secure the files and protect them from unauthorized modification.
- f. Store the files in an environment that will slow deterioration and maintain them while they are in storage.

Handling of the electronic CADD files received by the Government client

The electronic files that the Government requires its A-E design contractors to submit with their design work are valuable documents. They can be used in many more different ways than could the tracings that contractors were formerly required to submit, but they can be mis-used in nearly as many ways. The nature of electronic files means that they can be easily modified without leaving a trace, that they will deteriorate if left alone for an extended period, and that a person calling one up from a disk or tape cannot tell if it is old or current, original or modified, correct or wrong.

There are serious deficiencies in the current practices for handling electronic files. These problems make it difficult to assure that when they are eventually needed, the stored files will contain the expected information in the correct form or that the information in the files can actually be used as had been intended.

File security

The interviews indicated that there are currently no consistent policies, standards, or procedures for receiving, storing, and handling electronic CADD files and other digital media the Government receives from its Contractors, and that many of these files have not been managed in a secure manner. The files have been stored in a variety of ways, including:

- a. On disk in an active electronic database.
- b. In an area controlled by the CADD system manager.
- c. On tape racks in spaces that may or may not be secured.
- d. In file cabinets near the Government Project Manager's desk.
- e. In the Government Project Manager's desk drawer.

Electronic files have been stored in a variety of ways within a single office, primarily at the discretion of the Government Project Manager. In many cases, the Project Manager's records of where project electronic files have been stored are sketchy and the information has been kept primarily in the Project Manager's head. This means in many cases this means that the electronic files have been unavailable in the Project Manager's absence.

There are also inconsistent policies on handling electronic files. The inconsistencies occur in the areas of:

- a. Who is permitted to have access to the files.
- b. How the files are distributed after their are received.
- c. How files are modified after they are received.
- d. Who is authorized to modify the files.
- e. How versions of the files are controlled.
 - (1) Where are the original files as they were received from the contractor?
 - (2) Where are copies of the original files located and how have they been modified since they were made?
 - (3) Will the changes made to different scattered versions of the files ever be reconciled?
 - (4) Where is the most current version of each file?
- f. Who is responsible and liable for the information on the electronic file?

discover that he no longer has hardware required to read them. It is nearly impossible to find a computer today that will read floppy disks that were made on an old Lanier, Wang, or Z-80 system.

- b. *Storage media* - The storage media for computer data have changed a great deal over the years and many people have discovered that the information they archived onto an old storage medium cannot be read on current input devices. It is difficult to find computer hardware that will still read perforated tape or punched Hollerith cards. Floppy disks (8-in.) are a curiosity, and it is becoming difficult to find a new computer that has a 5-1/4-in. drive. Archived data that were stored in these formats may become impossible to read. In the same way, the 3-1/2-in. floppy that is so common today may become obsolete in just a few years.
- c. *Operating system* - Computer operating systems have changed significantly over the years and data that were stored under an obsolete operating system or an early version of a current operating system may no longer be accessible. Data that were recorded under C/PM is probably inaccessible today. There may once have been an upgrade or conversion tool available back when applications migrated from C/PM to DOS or other systems, but it would be very difficult to locate these utilities today. In the same way, DOS will probably be replaced in the market before much longer. In fact, several self-proclaimed replacement systems are contending for a share of the market and experts have predicted that Microsoft's Chicago or Windows95 system will replace DOS.

Technical obsolescence of electronic files

Many Government offices and project end users may believe that the electronic files they receive from their A-E design contractors will serve as long-term archives of the design documents of their projects. They put the files into storage expecting that several years later they will be able to retrieve the files and be able to use them. This hope is not realistic.

Electronic files that are in storage can become technically obsolete in several ways:

- a. *Hardware* - The hardware on which the files were originally created can be replaced by updated hardware systems and the person who originally stored the files may

- d. *CADD basic and application software* - Application programs, including CADD systems and design programs, are revised and upgraded frequently. Minor upgrades

may be released several times each year and major upgrades may occur every year or two. Some upgrades work transparently and a file that was made under the previous version of the operating system can be called up directly from the new version. Other upgrades are more complex and involve modifications to the format of the data files that the program creates. This means that files created under the previous version of the program must be converted before they will run under the upgraded system.

Sometimes the conversion requires the user to undertake a specific conversion process. Sometimes the conversion runs automatically whenever the user loads an old file into the upgraded program and a display box appears to inform the user of the conversion. Sometimes, though, the user does not even know that the conversion is taking place. In either case, a conversion occurs and the structure of the data file is modified.

This poses no problem if the data files are active and the files are converted with each upgrade. It is a problem, though, when a data file is several versions old and the utilities to make the intermediate upgrade steps are no longer readily available.

Natural deterioration of electronic files

Most contemporary computer files are stored on magnetic storage media as patterns of electrical charges. These electrical charges can be damaged in a number of ways through physical harm to the storage medium (by someone labeling a floppy disk by pressing down hard with a ball-point pen, for example) or by contact with magnetic or electrical fields (accidental contact with a magnet, for instance). In addition, the electronic file simply dissipates with time.

Magnetic storage media typically carry a 1-year warranty. Anyone who saves electronic files must expect that they will start to deteriorate sometime after that year ends. An old audio tape that has lost some of its electronic charge can still be played acceptably well in your stereo. A CADD drawing, on the other hand, cannot lose any of its charge and still remain useful (after all, which 3 percent of your drawing data can you do without?).

The life of electronic files on tape or disk can be prolonged by storing them in an environment with controlled temperature and humidity. For real security, though, archived electronic files should be copied onto new tape or disks annually.

3 CADD Services Cost Estimating Methods

The Contractor can recover project specific payroll costs by simply charging the appropriate staff time to the project. Project specific costs for materials and services (off-site plotting, for example) can be recovered as reimbursable expenses wherever they are permitted in the design contract.

Recovering firm-wide CADD costs that are not project specific is more difficult. The two basic approaches for doing this is by the hourly rate or firm-wide overhead rate.

Many Government Project Managers spend little time estimating the cost of preparing project CADD files. They prepare these estimates without devoting enough attention to fine-grain details. Typical CADD cost estimates are based on approximate sheet counts, previous experience, old rules of thumb, and a feeling for what feels right for overall project costs (of which CADD production costs are actually only a small portion).

Hourly Rate

The A-E design contractor can charge a specific hourly rate for using his CADD system on a project. The Contractor can charge this hourly rate for every hour a staff member spends using a CADD system to produce project work. The purpose of this rate is to offset the appropriate portion of the Contractor's firm-wide CADD

costs. The FAR specifies that the rate charged can only offset the actual costs incurred and that the rate is subject to audit.

The hourly rate method was most popular during the early days of CADD when CADD system prices and the resulting firm-wide costs were quite high and when the CADD system was used on only some of the projects in the A-E design contractor's office. In such situations, only those projects on which the CADD system was used were required to pay a share of the firm-wide CADD costs. The drawback to this approach is the high cost of administering the system. The Contractor must calculate the cost initially and then recalculate it periodically. The Contractor must justify the cost to the Government client and submit to an audit of the cost. The Contractor must gather utilization data and prepare invoices for each project.

Firm-Wide Overhead

Alternatively, the Contractor can include firm-wide CADD costs in the firm's overhead and thus spread them evenly over all projects within the firm. This approach is more popular today now that CADD systems are less expensive and A-E design contractors use CADD on almost all projects in the office. Questions about the fairness of charging a specific project for a share of the CADD system are seldom a significant issue. Avoiding the cost of maintaining a

utilization-logging and billing system is a popular feature of this option.

The FAR allows the A-E design contractor to use either of these two cost-recovery methods, but requires the contractor to use a single method for all work it performs on projects that have any federal funding. FAR does not permit the contractor to alternate charging methods on different projects.

Current Practice

Many A-E design contractors still levy an hourly CADD charge rate. These Contractors tend to be firms that have had CADD systems for several years and that originally installed the more expensive CADD systems (the old VAX-based Inter-graph system, for example). It is difficult for these firms to switch their cost-recovery methods because contracts for ongoing long-term projects that began with an hourly charge rate cannot easily be modified. The *CADD Applications and User Survey* of the Professional Services Management Journal (1994b) indicates that among the responding firms that charge an hourly rate for CADD use, the median hourly rate is \$20 and the mean rate is \$22.

Consulting firms that installed their CADD systems more recently and installed lower-cost CADD systems (generally PC-based systems) tend to include their firm-wide CADD costs in their overhead. These firms were able to start their CADD operations with their CADD costs in overhead and they are not forced to close out older projects with contracts that included an hourly CADD charge.

The hourly CADD charge is not a popular method of billing. Contractors generally find it cumbersome and expensive to administer. They also find it a troublesome issue during negotiations with clients. Corps project staff indicated during the interviews that they do not like to see the CADD cost shown as a separate

hourly rate. They would rather see it included in the Contractor's overhead.

The trend among A-E design contractors nationally seems to be toward including CADD costs in firm overhead. Contractors who are just beginning to do CADD work almost all adopt this approach. The Contractors who have been levying an hourly CADD charge tend to be reducing their charge rate (as they adopt less expensive CADD systems and as their firm-wide CADD costs decrease) or to be dropping the charge entirely and shifting the costs into overhead.

Estimating Costs for CADD Services

The interviews indicated that most current estimates of CADD product development costs *are not being made* by people who have direct CADD experience. This applies equally both to the estimates made by Contractors and to the estimates made by Government Project Managers.

Typically, a principal or project manager develops the A-E contractors CADD cost estimate, and a Government Project Manager develops the Government's CADD cost estimate. These people *do not have hands-on CADD experience* and typically *they do not understand* what it costs to produce CADD work. In particular, they do not generally understand the project-specific CADD costs that are not connected with actually producing the project drawings.

The typical person who now prepares CADD cost estimates — either the estimates included in the proposals the Government receives or the estimates the Government uses to evaluate these proposals — began estimating project document production costs before CADD systems were a factor. These cost estimators developed their feel for production costs during the days of hand-drafting and they prepare their current estimates

for CADD costs based on rules of thumb that originated back in hand-drafting days.

A typical cost estimate for CADD work is based on an hours-per-sheet number which originated for hand drafting and which may have been altered slightly to account for CADD systems. For example, the estimator may calculate costs on the basis of X drawing sheets in the project times Y hand-drafter hours per sheet times a 75-percent contingency factor to account for an CADD's estimated 25-percent increase in productivity.

Such rule-of-thumb estimates may be helpful in the early stages of a project, but they omit some important factors.

- a. They do not account for differences in the complexity of the project CADD specification/standard, or “learning curve.” Some standards are harder to meet than others, and the cost of meeting them will differ accordingly. It is noted that the Government may expect the Contractor to “absorb” these costs if the setup costs are a one-time occurrence and the Contractor will be accomplishing a considerable amount of work for the Government client.
- b. They do not account for the preproduction time required to set up to perform the project CADD work. These costs tend to be relatively independent of project size, so they can be a much bigger factor for a small project. However, these costs are normally included in the Contractor's overhead.
- c. They do not account for a CADD system's ability to reuse common material from one drawing sheet to another. This capability can represent significant savings on a project that includes a lot of repetition or similarity (or is similar to an earlier project).

As CADD systems become more powerful and as A-E design contractors automate their work more fully, it becomes more difficult to use the old rules of thumb.

a. *Drafting hours per drawing sheet.* For years of production, cost estimates have been made on the basis of the number of drafting hours required per drawing sheet. As CADD systems become more common and as contractors become more skilled at using them, the old hours-per-sheet rule of thumb becomes less and less useful.

- (1) In the pre-CADD era each drawing sheet had to be individually hand drawn. During this time, many A-E design contractors kept detailed records of how many hours were spent drawing each sheet. As a result, a Contractor with many years of experience doing a certain kind of design work could look at a new project and have a very good idea of how many drafting hours would be required to prepare each drawing sheet.
- (2) Well-managed CADD systems let the user develop graphic material for one drawing and then reuse it on other drawings in the set (and even save it for reuse on the next similar project). An accurate cost estimate for project CADD work must include an evaluation of which material can be developed once for the project and reused on several drawings. It must also include an analysis of what material from previous projects can be used on the current project, either as-is or with minor editing.

Making an accurate CADD cost estimate on the basis of drafting hours per sheet does not necessarily yield accurate results. Instead of using this rule of thumb, the estimator must evaluate the required sheets individually for the specific project

Validity of old rules of thumb

and look for ways the CADD system can be used to enhance productivity on each sheet.

b. Ratio of professional staff to technical staff. In the days of hand drafting, many A-E design contractors (particularly engineers) included many nonprofessional, technical staff members on their project teams. These technical staffers included detailers, drafters, tracers, etc., who produced many of the project drawings. Project production work required a fairly predictable ratio of professional staff payroll hours to technical staff payroll hours. For drawing production work, the ratio of professional to technical hours might range between 1:3 and 1:5.

(1) CADD implementation is changing this ratio. CADD systems allow the professional staff to do more of the drawing production work themselves. The professional staff uses design software that produces graphics as it performs calculations. The graphics, which drafters once might have had to draw from scratch, emerge from the design software in a complete enough state that a drafter only needs to perform a small amount of clean-up work.

(2) Easy-to-use computer drawing tools often make it easier for the professional to do some of the drawing work himself than to prepare complex instructions for the drafter and then supervise the drafter's work. Windows-based systems and systems that include a Graphic User Interface require even less user training.

The professional staff member can organize a drawing set and call up a significant amount of material from existing libraries rather than having drafters develop it from scratch.

The staffing mix in many consulting firms is changing significantly and nowadays it often includes many more professionals than technicians. Consulting offices which have automated their operations tend to report that:

They have fewer technicians on staff than they did previously.

They expect to have even fewer technicians in the future.

The technicians they will keep must have discipline-based knowledge and skills that extend beyond simple drafting.

As a result, an accurate CADD cost estimate may show an unexpectedly high ratio of professional hours to technical hours, considerably higher than would have been found during the hand-drafting era.

A person who is making a CADD cost estimate must be prepared to set the old rule of thumb aside and look at the specific project situation. The estimator must evaluate all project cost factors and develop a total project CADD cost. The validity or attractiveness of an estimate or proposal can be evaluated only by looking at the total cost.

c. Ratio of design time to drawing production time. During the hand-drafting era, design work and the production of contract drawings tended to be separate efforts. The design team first made sketches and calculations, then made design decisions, and then passed the work on to the production staff to produce the contract drawings. This process tended to result in a distinct design phase that was followed by a distinct contract drawing production phase, and estimators allocated standard percentages of the design fee to each phase.

Recent CADD systems advances have blurred

the line between design and con-tract drawing production. Designers now perform part of their work directly on the CADD systems. Production staff may help them produce complex design models. Designers use calculation-driven design software that generates graphic computer models. At the end of the design process, the designers have often produced a sophisticated computer model of the design which can provide a significant head-start to the drawing production effort. The production staff may discover that much of their start-up work has al-ready been done for them automatically during the “design” phase and that their part of the work in the “drawing produc-tion” phase does not take as long.

Old assumptions about the expected ratio between design time and production time do not necessarily continue to hold true. Here, too, the person estimating CADD costs must be ready to ignore the old rule of thumb and look at the specific project. The estimator must look at the total costs for the design and production phases and evaluate validity or attrac-tiveness of the estimate or proposal in terms of this total cost.

Changes in overhead costs and payroll multipliers

In examining proposals from A-E design contractors, Government Project Managers tend to evaluate the Contractor's over-head as a percentage of payroll costs. Many client agencies have informal or formal written guidelines on maximum permissible overhead rates based on the percentage of payroll costs. If the Con-tractor's proposed overhead rate is higher than the guideline, the proposal will be rejected or at least questioned. Some Government client agencies (pri-marily at the state level) operate under legal requirements that a Contractor's overhead rate shall not exceed a specified percentage of payroll. Caps on overhead rates are specifically prohibited in the USACE.

In most cases, these guidelines and rules of thumb were developed for a hand-drafting

technology and the legislated overhead caps obviously do not allow for advanced technology. These overhead guidelines were developed when the A-E design contractor's practice was much more labor intensive than today and while capital costs were relatively low.

They were developed during a time when design calculations and contract drawings were produced by hand; when the designer's capital equipment included ordinary office furniture, typewriters, mechanical calculators, and perhaps an ammonia-based blue-print machine; when office-space amenities were limited to steam radiators and strip fluorescent lights. Labor costs represented a high percentage of the Contractor's total cost, while capital and operating costs represented a low percentage.

The situation has changed since these guidelines were developed. The A-E design contractors' labor mix has changed, as was described above. Contractors now use more professional staff members and less technical staff and everyone on the Contractors' staff is under great pressure to show more productivity.

Capital costs are increasing. Contractors are increasing their productivity and reducing payroll costs by investing in sophisticated automated tools such as advanced communication systems, word processing systems, CADD systems, and automated design software. These tools increase overhead costs while allowing the contractor to reduce payroll costs.

Space costs are increasing. Accommodating the automated tools just mentioned requires office space with better environmental controls, better lighting, more highly articulated power distribution, and with sophisticated cabling for telephone and other data systems. Such space costs significantly more than did space with steam radiators and strip fluorescent lights.

Contractors have adopted these automated systems partly because of general changes in the way their professions are practiced. They have

also incorporated these systems into their practices because their clients have required that they deliver their contract documents in electronic format — as word processing files, CADD files, design files, etc.

Because of these changes, a typical Contractor's payroll costs have remained steady or decreased, while at the same time, overhead costs have gone up. Many Contractors find themselves having trouble meeting their clients' guidelines for overhead as a percentage of payroll costs. As a result, some Contractors have resorted to methods such as:

- a. Levying an hourly charge for CADD usage to show CADD costs as a separate item that is not included in the general firm-wide overhead rate.
- b. Performing work in labor-intensive, nonautomated ways so as to increase the ratio of payroll costs to overhead costs.

The first expedient is an accounting decision that does not significantly affect total project cost (though it does incur the additional costs of administering the system, as was described above). The second dodge decreases staff productivity and increases overall project costs (though it does keep the firm's overhead percentage within the client's guidelines).

Hard guidelines on overhead rates as a percentage of payroll costs can be counterproductive and actually increase project costs. The nature of automated productivity tools and client requirements that Contractors must use these tools tend to increase the Contractor's overhead as a percentage of payroll and at the same time reduce overall project costs. Client agencies must recognize this change as they evaluate proposals.

Trends

Estimating CADD costs on a basis of drawing hours per sheet works well enough for preliminary estimates, provided that the person making the estimate keeps track of changes in productivity. This method works less well for making detailed estimates when the CADD operation has access to an extensive, well-organized library and the CADD production staff makes careful use of reference files and of material that can be used more than once.

The ratio of professional staff hours to technical staff hours spent producing project

CADD work will increase as professional staff produce more of the finished CADD work themselves and as the number of technicians on consulting firm staffs decrease.

As Contractors use expensive automated systems to increase their productivity, their operations will become more capital-intensive. The ratio of overhead to payroll costs will increase.

4 Recommendations

Payment for CADD Services

It is recommended that all firm-wide CADD costs be included in the A-E contractor's overhead rate and *not* included in a separate hourly rate just for CADD related work. Project-specific CADD costs specifically related to manhours for drafting and design of project features should simply be the length of time it takes the appropriate member of the A-E contractor's staff to actually perform the work using the CADD system. Other project-specific CADD costs (e.g., scanning, electronic deliverable media, etc.) should be itemized by the A-E contractor on his proposal.

Suggested Estimating Procedures

Rules of thumb and the estimator's past experience with drafting-by-hand procedures are sufficient for making preliminary order of magnitude estimates of CADD services costs. However, in order to obtain the more accurate level of detail required to negotiate contract and delivery order costs, the estimator must work at a higher level of detail. It is recommended that the Government and A-E contractor estimator evaluate the following factors during the preparation of the cost estimate. In addition, both the appropriate Government and A-E contractor personnel should develop a clear understanding of the following factors prior to the Government's submitting a RFP to the A-E contractor.

The CADD Standard

Evaluate the CADD Standard required for the project. Determine whether the required standard includes everything that is needed for the project at hand. If the CADD standard is new, determine how similar the project CADD standard is to the other standards already being used.

For small or specialized types of design projects, the CADD Standard could be tailored to the project. Determine which portions of the whole CADD Standard document are required for the project and agree not to use the portions that do not apply. Decide how to handle project issues that are not included (or are just not clear) in the CADD Standard. Confirm these understandings with all parties to the project — the Government design/ construction office, the A-E design contractor, and the project end user. The ideal situation would be for the Government to prepare a summary of the job-specific CADD Standards to be used by the A-E contractor and to provide the summary as a part of the GFM's. The summary could either (a) include the actual CADD Standards which are relevant to the design project, (b) reference the portions of the Government's general CADD Standard which are applicable to the design project, or (c) include a combination of both.

If the CADD Standard is new, estimate how much time the A-E contractor will need to tool up to use the standard. Tooling up to use the standard involves the following considerations. These considerations do not apply when the

project CADD Standard has been in common use prior to the project. They do apply when the project CADD Standard is new or is significantly changed from previous standards.

- a. How much time will be required to study and absorb the standard?
- b. How much time will be required to develop menus and user commands and to develop new electronic libraries? This requirement can be eliminated if the Government provides electronic seed files/prototype drawings which are configured for the CADD Standard to the A-E contractor.
- c. How much time will be required to train the Contractor's CADD staff and how much time will they need to pass through the learning curve and regain their previous level of productivity?
- d. Estimate the staff productivity differences between following the project CADD Standard and following other current or other previous standards. This will probably be a percentage factor.

Government-furnished materials (GFM's)

Electronic cell libraries. Examine the electronic symbol and detail cell libraries to be delivered to the Contractor. Determine how much of it will really apply to the project (and how much of it is just standard library material that is of no immediate use for the specific project). Also, determine if the detail libraries are configured to the required CADD Standard, and whether the Contractor must redraw or modify them to comply with the standard. Estimate how much time the contractor will save using this material.

Electronic seed files/prototype drawings/workspaces. Does the Government have electronic seed files, prototype drawings, and/or workspaces which are configured to the required CADD Standard to provide to the A-E

contractor? This material can save a considerable amount of the Contractor's time.

Information on existing conditions. Evaluate the content and quality of the data and material to be provided to the contractor. Estimate how much time and effort receiving this material will save the Contractor. Estimate how hard it will be for the Contractor to use the material. Is the electronic data in a format readily accessible to the CADD software to be used?

Estimate the time and cost required to convert hard copy (paper or vellum) drawings to an electronic format compatible with the CADD software to be used on the contract. Also determine if the drawings will be required in a raster or vector electronic format, and estimate the cost of producing the type required.

Drawings the Contractor will deliver to the Government

Estimate the number of drawing sheets that will be included in the set. Organize the list of required sheets by discipline. Evaluate the density and complexity of each sheet or sheet type. Identify any special conditions that will require more or less than an ordinary level of effort.

Data structure. Evaluate the project directory and file structure. Evaluate the data structure required by the design contract or sketch out an approximate data structure. Estimate how reference files can be used to save the Contractor time.

Reused material. Determine how much material can be developed for one drawing and then reused on other drawings with only minor changes. Estimate how reusing this material can impact the cost of producing other project drawings.

Reference files. The reference file tools included in current CADD systems give the user significantly improved capability to layer CADD drawings and to develop graphics such as drawing

borders, title blocks, and project base conditions as reference files and include them in many composite project drawings. Estimate how the Contractor can use reference file capabilities to save time.

Rules of thumb. Be ready to question old cost-estimating rules of thumb and look instead to total cost.

- a. Reference files and the ability to use the same material several places in a set of drawings may invalidate earlier estimates based on the required number of drawing hours per sheet.
- b. Changes in the Contractors' staffing mix and the new ways professional staff can use a CADD system to create a greater portion of the finished drawings will change the traditional ratio of professional staff hours to technical staff hours.
- c. Increases in staff productivity and increased capital costs for automated equipment increase over-head costs as a percentage of payroll.

Interim submittals

Determine how many electronic deliveries the Contractor is required to make. Each required interim electronic submittal represents a cost. Determine when each interim electronic delivery must be made. Determine what must be included in each electronic delivery — which drawings must be included and what information must be included on each drawing? Estimate the cost of making each electronic delivery — assembling the files, verifying their contents, writing them to disk or tape, administering the transmittal and delivery.

Final delivery

Determine what the Contractor must include in the project delivery at the end of the design process. Estimate the cost of preparing this delivery — assembling the files, verifying their

contents, writing them to disk or tape, administering the transmittal and delivery.

As-built drawings

Determine whether the A-E design contractor is required to develop as-built drawings at the end of construction and, if so, whether he is responsible for gathering as-built information from the construction site. Estimate the cost of modifying the CADD files to reflect changes made during the construction process.

Archiving

Determine whether the A-E design contractor is required to archive the project CADD files after the project is finished. Estimate the initial cost of archiving the material and the periodic cost of maintaining the archive.

Suggestions For Reducing CADD Costs

Project team communication

Facilitate direct contact between the A-E design contractor, the appropriate technical staff, and the end user of the design project wherever possible. When all communications between the Government, the A-E contractor technical staff, and the end user go only through the Government and A-E contractor project managers, communications involve extra steps, take longer, and are subject to confusion. The Contractor may never really know what the end user wants. Also, the Contractor's technical staff may not have access to the knowledge and experience possessed by the Government's technical staff which could reduce project design costs and improve the finished project design. If a Contractor suspects that his access to the end user or Government's technical staff will be limited, his proposal may include fee allowances to cover the cost of making changes and back-tracking and time allowances to cover delays.

The best way to establish lines of communication and to ensure that all parties have a clear understanding of the project scope is to hold a meeting at the project site to include the Government and A-E project managers, the appropriate Government and A-E technical staff, and representatives of the end user attending. If possible, this meeting should be held prior to the Government's submitting the RFP to the A-E contractor. Lines of communication have to be established and clearly understood by all parties. For instance, all communications and decisions which could impact the A-E contractor's design cost, the project construction cost, or project design schedule must be coordinated through the Government and A-E contract managers. Communications and decisions on technical issues, such as foundation design for a building, should be coordinated between the appropriate technical staff. Communications and decisions concerning color schemes for buildings, and similar issues, should be coordinated between the appropriate technical staff and representatives of the end user.

The contract provisions should include the requirements of Part 1.1 of the Tri-Service Standards, entitled "A-E CADD Deliverables Standards."

Ultimate file use

Determine how the required electronic CADD files are to be stored, archived, and used in the future by the Government. Do this before the project SOW is prepared and convey the information to the A-E design contractor as early in the project as possible. This knowledge will provide a context within which to approach many of the CADD-related questions that are certain to arise during the project.

Delivery requirements in contract language

Include a clear and complete description of the electronic CADD delivery requirements in the language of the contract. If the contract describes the CADD requirement in just a sentence or two, the contractor is left to guess what the final requirement will be. The contractor who is forced to make such a guess will try to protect himself with a higher proposal.

Clear, uniform, and easy to understand CADD Standard

Use a clear, uniform CADD Standard. Implement it as broadly as possible. The Contractor who can complete a project for one Tri-Service component and then start another project for a different component that uses the same CADD Standard can do his work with confidence and with increased productivity. The ultimate adoption and use of the *Tri-Service A/E/C CADD Standards* (TSTC in preparation) being developed at the TSTC by the DoD will provide this.

Keep the project CADD Standard as simple as it can be and still accomplish the project's goals. Meet with the contractor at the start of the project and determine which portions of the overall CADD Standard apply to the specific project and which do not apply. Develop a subset of the official CADD Standard that describes how CADD work will be approached for the specific project.

For example, a Project Manager and A-E design contractor might agree to simplify the level names for a simple project or for the simple portions of a larger, more complex project. In such a situation, consider grouping project data on a single level with the four-character BASIC level name (as described in the draft *Tri-Service A/E/C CADD Standards* (TSTC in preparation)). Organize the data into multiple layers that use the 9-character STANDARD format or the 13-character USER-DEFINED format only when the project or project segment is complex enough to warrant the effort.

For small or specialized types of design projects, the CADD Standard could be tailored to the project. The ideal situation would be for the Government to prepare a summary of the job-specific CADD Standards to be used by the A-E contractor and to provide the summary as a part of the GFM's. The summary could either (a) include the actual CADD Standards which are relevant to the design project, (b) reference the

portions of the Government's general CADD Standard which are applicable to the design project, or (c) include a combination of both.

Government-furnished electronic data

Provide the Contractor with electronic tools that will expedite his work.

a. Library material.

- (1) Provide seed file or prototype drawings with cell libraries of symbols and details, font libraries, line type/style libraries, and level/layer schemas that are configured for the Government's CADD Standard. Provide electronic workspaces with custom menu structures and user commands that will automate layering and simplify access to the libraries. The TSTC is developing these products for use with the *Tri-Service A/E/C CADD Standards* (TSTC in preparation). The use of this electronic material, along with any additional customization which may be necessary for the particular Government organization's requirements, can be used to save the A-E design contractor's time (and consequently reduce their fees). In addition, providing this material can improve the quality of the files that the contractors eventually deliver to the Government by making it easier for their CADD staff to follow the CADD Standards and by ensuring uniformity of implementation of the CADD Standards.
- (2) Provide standard electronic construction details (e.g., fire hydrants, man-holes, etc., configured to the CADD standards) for the items of construction which are always installed or constructed the same way (or which may require only minor

modifications) to the A-E contractor.

However, requiring the A-E contractor to use old electronic details and to modify them to conform to the CADD Standards may cost more than allowing the contractor to redraw them from scratch, or over a scanned raster image of the detail.

b. Project-specific data.

- (1) Provide the A-E design contractor with any existing project data that might be helpful. This might include base material, data on existing site conditions, information from previous project phases, etc. Before delivering this data to the contractor, the material must be reviewed to verify that the electronic files are complete, readable, and usable. Verify, too, that the information included in the files is accurate. Be prepared (if accuracy of the data is a critical issue) to certify the accuracy of the data or pay the contractor to verify the data.
- (2) If possible, provide the A-E contractor with a copy of the plans and specifications for a previously completed design project that is similar to the one to be designed. However, make sure it is clearly stated on the plans and specifications or in the design contract SOW that the information is provided “For Information Only” and is not to be used verbatim by the A-E contractor.
- (3) Hard-copy, or paper, drawings depicting as-built and existing conditions can be provided to the A-E contractor to provide background information for use in the design process. For the portions of the design where the general locations of existing and proposed features are to be shown (e.g., general plans), the drawings can be scanned and incorporated into the

project drawings. Aerial photographs are very useful for this purpose also.

Project meetings

Project meetings should be held at key milestones during the life of each project.

An initial project meeting should be held prior to the development of the A-E's proposal (i.e., preproposal conference). CADD related issues (e.g., the CADD standard, CADD deliverables requirements, Government furnished electronic and hard copy data, and future uses of the data) should be discussed at this time. Include representatives from the end user, the Government project manager, the appropriate Government technical experts (as applicable), the A-E design contractor project manager, and the appropriate A-E technical experts (as applicable) at the meeting. Clarify expectations of all involved.

Define specific responsibilities. Define the project schedule and the procedures to be followed.

Electronic file testing

Exchange and test sample electronic files. Test the electronic files to be delivered from the Government to the Contractor before the RFP is submitted to the A-E contractor. Test the files to be delivered to the Government by the Contractor before serious CADD production work begins. Verify that the files: (a) contain the required information, (b) are done in the correct format, (c) follow the project CADD Standards, and (d) can be used for the purposes intended.

Interim electronic format submittals

Determine how many interim submittals the Contractor is required to make in electronic CADD format. What is the value to the Government of these interim electronic submittals? Reduce the number of required electronic submittals to the minimum number that will give the Government this desired value. Reduce the portion of each interim submittal that must be made in electronic format to the minimum that will give the Government this value. The fewer times the Contractor must submit electronic files and the less material the Contractor must submit in electronic format, the lower the Contractor's CADD costs will be.

Professional liability

Resolve professional liability questions before the work begins. A Contractor who feels uncertain about his exposure and feels he must protect himself will add money to his proposal.

Checklist and Sample Spreadsheet for Preparing Estimates

A checklist and sample spreadsheet for guidance in preparing cost estimates for A-E CADD services are included in Appendices B1 and C1, respectively.

References

Commerce Business Daily. Superintend of Documents, Government Printing Office, Washington, DC

Headquarters, Department of the Army. (1990). "Standards manual for U.S. Army Corps of Engineers computer-aided design and drafting (CADD) systems," Engineer Manual 1110-1-1807, Washington, DC

Professional Services Management Journal. (1994a). "Design services fee structure survey," Newton, MA.

_____. (1994b). "CADD applications and user survey," Newton, MA.

Systems Management Consultants. (1993). "CADD risk management for design firms," Overland Park, KS.

_____. (1994). "Contracting for CADD work: A guide for design professionals," Overland Park, KS.

Tri-Service Technology Center. "Tri-Service Architectural, Engineering, and Construction (A/E/C) Computer-aided Design and Drafting (CADD) Standards, report 1, Standards manual," Technical report in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

_____. "Tri-Service standards, part 1.1, Tri-Service A-E CADD deliverables standards," technical report in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Appendix A

Glossary

ACEC	American Consulting Engineers Council
A-E	Architect-engineer firm
A/E/C	Architectural, Engineering, and Construction
A.I.A.	American Institute of Architects
Application	Software designed to meet software specific needs and perform specific tasks, unlike system software which runs other software
AutoCAD	CADD software program developed by Autodesk, Inc., registered and trademarked by Autodesk, Inc.
CADD	Computer-aided design and drafting
CBD	<i>Commerce Business Daily</i>
CO	Contracting Officer
COR	Contracting Officer's Representative
Database	A collection of electronic information organized for easy retrieval. Databases are organized into a hierarchy of files having a predetermined structure and organization that can be communicated, interpreted, or processed by a specific program
DoD	Department of Defense
GFM	Government Furnished Materials
GIS	Geographic Information System
FAR File	<i>Federal Acquisition Regulations</i> A group of related information

File format	A defined digital organization and arrangement that determines how a computer file will be written and displayed on screen or in print
MicroStation	The CADD software program developed by Bentley, Inc., registered and trademarked by Bentley, Inc. It is used, and marketed, by Intergraph, Inc., as the “basic” CADD program (or CADD engine) for many of its CADD application and GIS software products.
MS-DOS	Microsoft Disk Operating System, a registered trademark of the Microsoft Corporation. Software that allows application programs to interact with the computer’s hardware and translates the user’s commands
Operating	A computer software program that provides commands and functions used by System other computer programs to communicate with the computer hardware equipment
PC	Personal computer with an Intel, or Intel-compatible, central processing unit. Normally contains a 486 or pentium central processing unit for CADD applications
RFP	Request for proposal
Scanner	An electronic device that converts an image from paper into a raster image stored in an electronic computer file
Software	An electronic digital program that contains instructions used to perform certain tasks on a computer or to manage a computer’s operation
SF	Standard Form
SMC	Systems Management Consultants
SOP	Standard Operating Procedures
SOW	Scope of Work or Statement of Work
TSTC	Tri-Service Technology Center
UNIX	The operating system and family of related utilities originally developed by AT&T Bell Laboratories
USACE	United States Army Corps of Engineers
USAED	U.S. Army Engineer District
Windows	Windows operating system software, a registered trademark of the Microsoft Corporation. Software that provides a graphical interface, allowing application programs to interact with

the computer hardware and translates the user's commands. Windows, version 3.1 and below, requires MS-DOS to operate

Windows NT Windows New Technology operating system, a registered trademark of the Microsoft Corporation. Software that allows application programs to interact with the PC or workstation hardware, translates the user's commands, and does not require MS-DOS to operate

Workstation A terminal that contains an internal central processing unit and can operate in a stand-alone mode or as part of a network

Appendix B

Check List

Cost Estimating for A-E CADD Services Check List

- ___ I. Review the project Scope of Work.
 - ___ A. What work is the design contractor required to perform?
 - ___ B. What parts of the work must be submitted as electronic CADD files?
- ___ II. Review the CADD Standard that is required for the project CADD work.
 - ___ A. Is this a new CADD Standard, one that has not been required for previous design contracts? If not, go to Item III.
 - ___ B. If this is a new CADD Standard, estimate how much time the design contractor will need to tool up to use the new Standard.
 - ___ 1. How much time will the contractor need to study and absorb the new standard?
 - ___ 2. How much time will the contractor need to develop menus and user commands and to develop new library materials and seed files?
 - ___ 3. How much time will the contractor need to train his CADD staff to use the new Standard and how much time will the staff need to pass through the learning curve and regain their previous level of productivity?
- ___ III. Review electronic data the Government will furnish to the design contractor.
 - ___ A. Seed files and cell libraries. Examine the material to be delivered and estimate how much time the contractor will save by using this material.
 - ___ B. Information on existing conditions. Evaluate the content, format, and quality of the material to be provided.

- _____ 1. Estimate how much time the contractor will save by using the material.
 - _____ 2. Estimate how much time it will take the contractor to sort out the material and use it.
 - _____ 3. Determine whether the Government will certify the accuracy of the material provided.
 - _____ 4. If not, estimate how long it will take the contractor to verify the information contained in the Government-furnished material.
- _____ IV. Evaluate the drawings that the design contractor will furnish to the Government
 - _____ A. Estimate the number of drawing sheets that will be included in the set.
 - _____ B. Organize the list of required sheets by discipline.
 - _____ C. Evaluate the density and complexity of each sheet or sheet type.
 - _____ D. Identify any special conditions that will require more or less than an ordinary level of effort.
 - _____ E. Data Structure
 - _____ 1. Evaluate the project directory and file structure.
 - _____ 2. Evaluate the data structure required by the design contract or sketch out an approximate data structure.
 - _____ 3. Estimate how reference files can be used to save the contractor time.
 - _____ F. Reused Material
 - _____ 1. Determine how much material can be developed for one drawing and then reused on other drawings with only minor changes.
 - _____ 2. Estimate how reusing this material can impact the cost of producing other project drawings.
 - _____ G. Estimate how the contractor can use reference file capabilities to save time.
- _____ V. Interim submittals
 - _____ A. Determine how many electronic deliveries the contractor is required to make.

- _____ B. Determine when each interim electronic delivery must be made.
- _____ C. Determine what must be included in each electronic delivery — which drawings must be included and what information must be included in each drawing?
- _____ D. Estimate the cost of making each electronic delivery — assembling the files, verifying their contents, writing them to disk or tape, administering the transmittal and delivery.
- _____ VI. Estimate the cost of making the final delivery. What will it cost to:
 - _____ A. Assemble the required files.
 - _____ B. Verify the contents of the files.
 - _____ C. Write the files to disk or tape.
 - _____ D. Administer the transmittal and delivery of the files.
- _____ VII. Estimate the cost of preparing as-built drawings. What will it cost to:
 - _____ A. Maintain the electronic files of the design drawings until the end of construction? What if there is a delay in funding and construction does not begin immediately after the design phase?
 - _____ B. Gather information from the construction site?
 - _____ C. Make the required changes to the design drawings?
- _____ VIII. Estimate the cost of archiving the CADD files. What will it cost to:
 - _____ A. Initially archive the project files?
 - _____ B. Maintain the archive for the required period?

Appendix C

Sample Spreadsheet

NOTE: The sample spreadsheet is included to provide a generic example of one way to set up an electronic spreadsheet to estimate costs that are specific to the development of CADD gen-erated products. The sample spreadsheet should not be construed to be comprehensive enough to cover all project specific parameters. The sample spreadsheet does not take into account the different diciplines of the A-E contractor's staff that will be doing the actual CADD work. Actual cost estimates should include estimates for the number of hours that each dicipline will spend performing the items of work.

An electronic copy of this spreadsheet in a Microsoft Excel (Version 5.0) can be obtained from the TSTC's internet homepage at <http://mr2.wes.army.mil>.

Appendix C - Sample Spreadsheet (with sample values)

HRS/ITEM	NET HRS	DESCRIPTION
	1.	THE CADD STANDARD
	a.	Does the project have a new CADD Standard? If no, enter 0 and move to Item 2. If yes, move to the next item (Item 1b).
	b.	How many hours will it take the Contractor to:
8	i.	Study and absorb the new Standard.
8	ii.	Develop new menus and user commands.
8	iii.	Develop new library materials and seed files.
	iv.	Train the CADD staff to use the new standard.
		4 # of CADD staff
		8 hours per person
32		32 total hours
	v.	Take the CADD staff through the learning curve and regain their previous level of productivity?
		4 # of CADD staff
		16 hours per person
64		64 total hours
120		SUBTOTAL HOURS
	2.	GOVERNMENT-FURNISHED MATERIAL
	a.	Seed Files and Cell Libraries. Answer one of the two lines. How many hours will it take the Contractor to:
	i.	Develop the material and set up to use.
24	ii.	Receive the material from the Government and set up to use.
	b.	Project base data. Answer one of the two lines. How many hours will it take the Contractor to:
	i.	Develop the material and set up to use.
32	ii.	Receive the material from the Government and set up to use.

iii. Does the Government certify the accuracy of the Government-Furnished Material?

If yes, move to item 3.

120

If no, how many hours will it take the Contractor to verify the data contained in the Government-Furnished Material? Verify whether these are considered CADD hours or something else.

176

SUBTOTAL HOURS

3. THE CONTRACTOR'S DRAWINGS. How many drawings must the Contractor prepare? Divide these into groups of similar drawings.

a. Group A.

22

i. How many drawings are in the Group?

28

ii. How many hours does it take to prepare each drawing?

616

Total Drawing Hours

-32

iii. How many hours can be saved by inserting seed file and library material?

-36

iv. How many hours can be saved by reusing material from one drawing to the next?

-12

v. How many hours can be saved by using reference file capability?

536

Subtotal for Group

b. Group B.

22

i. How many drawings are in the Group?

28

ii. How many hours does it take to prepare each drawing?

616

Total Drawing Hours

-32

iii. How many hours can be saved by inserting seed file and library material?

-36

iv. How many hours can be saved by reusing material from one drawing to the next?

-12

v. How many hours can be saved by using reference file capability?

536

Subtotal for Group

	c.	Group C
22	i.	How many drawings are in the Group?
28	ii.	How many hours does it take to prepare each drawing?
616		Total Drawing Hours
-32	iii.	How many hours can be saved by inserting seed file and library material?
-36	iv.	How many hours can be saved by reusing material from one drawing to the next?
-12	v.	How many hours can be saved by using reference file capability?
536		Subtotal for Group

ADD MORE GROUPS AS REQUIRED

1,608 SUBTOTAL HOURS

4. INTERIM SUBMITTALS

3	a.	How many interim submittals is the Contractor required to make?
	b.	How many long will it take the Contractor to make the first interim submittal? How many hours will it take to:
4	i.	Assemble the files.
12	ii.	Verify file contents.
4	iii.	Write the files to disk or tape.
16	iv.	Administer the transmittal and delivery.
39		Subtotal for Submittal
	c.	How long will it take the Contractor to make the second interim submittal? How many hours will it take to:
4	i.	Assemble the files.
12	ii.	Verify file contents.
4	iii.	Write the files to disk or tape.
16	iv.	Administer the transmittal and delivery.
36		Subtotal for Submittal

- d. How long will it take the Contractor to make the third interim submittal? How many hours will it take to:
 - 4 i. Assemble the files.
 - 12 ii. Verify file contents.
 - 4 iii. Write the files to disk or tape.
 - 16 iv. Administer the transmittal and delivery.
 - 36 Subtotal for Submittal

ADD MORE SUBMITTALS AS REQUIRED

108 SUBTOTAL HOURS

- 5. FINAL SUBMITTAL. How long will it take the Contractor to make the final submittal? How many hours will it take to:
 - 4 a. Assemble the files.
 - 12 b. Verify file contents.
 - 4 c. Write the files to disk or tape.
 - 16 d. Administer the transmittal and delivery.
 - 36 SUBTOTAL HOURS

6. AS-BUILT DRAWINGS

- a. Is the Contractor required to prepare as-built drawings?
 - If no, enter 0 and move to item 7.
 - If yes, move to the next item.
- b. How many hours will it take the Contractor to:
 - 80 i. Archive the files for the design drawings until the end of construction.
 - 360 ii. Gather as-built information during construction on the job site, if required.
 - 32 iii. Receive and evaluate the as-built information.
 - 80 iv. Make required changes to the design drawings.
 - 24 v. Prepare and make the CADD file delivery.

576		SUBTOTAL HOURS
	7.	CADD FILE ARCHIVES
	a.	Is the Contractor required to archive the project CADD files?
		If no, enter 0 and move to the bottom of the sheet.
		If yes, move to the next item.
	b.	How many hours will it take the Contractor to:
24	i.	Initially archive the files.
72	ii.	Maintain the archive for the required period.
96		SUBTOTAL HOURS
		SUBTOTALS
120	1.	THE CADD STANDARD
176	2.	GOVERNMENT-FURNISHED MATERIAL
1,608	3.	THE CONTRACTOR'S DRAWINGS
108	4.	INTERIM SUBMITTALS
36	5.	FINAL SUBMITTAL
576	6.	AS-BUILT DRAWINGS
96	7.	CADD FILE ARCHIVES
2,720		TOTAL HOURS
\$25		AVERAGE HOURLY RATE FOR DISCIPLINE (e.g., draftsman)
\$ 68,000		TOTAL DIRECT PAYROLL COST FOR THE PRODUCTION OF CADD PRODUCTS.
\$ 34,000		150% OVERHEAD (If not included in the negotiated hourly rate).
<u>\$ 6,800</u>		10% PROFIT (If not included in the negotiated hourly rate).
\$108,800		TOTAL DIRECT PAYROLL COST FOR THE PRODUCTION OF CADD PRODUCTS (WITH OVERHEAD AND PROFIT).

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 1996	3. REPORT TYPE AND DATES COVERED Final report	
4. TITLE AND SUBTITLE Estimating Costs for Architect-Engineer (A-E) Computer-Aided Design and Drafting (CADD) Services		5. FUNDING NUMBERS	
6. AUTHOR(S) Bobby G. Carpenter, John F. Hill, Michael P. Ingardia		8. PERFORMING ORGANIZATION REPORT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road, Vicksburg, MS 39180-6199; Systems Management Consultants, Inc. 14109 Woodward, P.O. Box 23145, Overland Park, KS 66223		10. SPONSORING/MONITORING AGENCY REPORT NUMBER Technical Report CADD-96-1	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		11. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This report provides guidance and recommended procedures for estimating the costs associated with the preparation of design drawings by architect-engineer (A-E) contractors using computer-aided and drafting (CADD) technology.			
14. SUBJECT TERMS A-E Architect-engineer CADD Computer-aided design and drafting		Cost estimating Design Government	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		15. NUMBER OF PAGES 47	
18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED		16. PRICE CODE	
19. SECURITY CLASSIFICATION OF ABSTRACT		20. LIMITATION OF ABSTRACT	

