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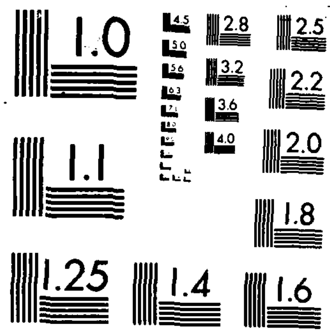

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

COMPUTER-AIDED SYSTEM NEEDS
FOR THE TECHNICAL DESIGN SECTION OF THE
BASE LEVEL CIVIL ENGINEERING SQUADRON

THESIS

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AFIT/GEM/DEM/86S-19

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the

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Master of Science in Engineering Management

James P. Mitnik, B.S.

First Lieutenant, USAF

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James P. Mitnik

Table of Contents

List of Tables

Abstract

The quantity of design, drafting, charts and maps required by todays Civil Engineering Squadron is increasing faster than the ability of civil engineering personnel to accomplish these tasks. One possible solution to this problem is the potential for computer-aided design and drafting (CADD) systems to increase productivity of our existing manpower and pay for themselves by decreasing expenditures for overtime and Architectural-Engineering (AE) contracts. This thesis determines by literature review and survey techniques to what extent officers in a base level technical design position would be able to design projects which are currently being designed by AE contract. Furthermore, this research determines the average size (designers, draftsmen, projects, dollars) of a base level technical design section. Finally, this research determines those software capabilities necessary in a CADD system for a base level design section, and determines how many CADD workstations would be needed by an average size Technical Design Section.

COMPUTER-AIDED SYSTEM NEEDS
FOR THE TECHNICAL DESIGN SECTION OF THE
BASE LEVEL CIVIL ENGINEERING SQUADRON

I. Introduction

Background

Air Force design programs have grown dramatically since the late 1970's. According to Captain Carl Clayton HQ AFESC/SI, in a report to the Air Force Computer Graphics Working Group:

> The growing volume and technical complexity of our operations, maintenance and construction programs have caused an increasing backlog in our design, drafting and comprehensive planning functions. The sheer mass of design, engineering drawings, charts and maps required by today's civil engineering organizations is rapidly overtaking the ability of our people to produce them. [27:1]

One possible solution to this problem is the potential for Computer-Aided Design (CAD) systems to increase the productivity of our existing manpower and potentially pay for themselves by decreasing expenditures for overtime and Architectural-Engineering (AE) contracts.

Since Fall 1984, there has been an explosion of CAD technology, especially in micro-based CAD. Studies have documented the benefits of CAD. The question for civilian AE firms today is no longer whether to implement CAD or not, but which CAD system to choose and how to implement the system (163:23).

Two particular studies related directly to the economic benefits of CAD for the Base Civil Engineering Squadron are Captain Mike Roberts' thesis, Automated Drafting and Design for the Base Civil Engineer and Captain William Duncan's thesis, Computer-Aided Design Applications for the Base Civil Engineering Technical Design Section. Both theses verify the applicability to the design area by showing increased manhours via CAD productivity and increased quality of designs and drawings using CAD systems.

But, before the Engineering Branch of a Civil Engineering Squadron buys Computer-Aided Design and Drafting equipment, one needs to take a good look at the design process.

> Design problems are not like scientific, mathematical, or logical problems, which generally require the proof

> of an (a) hypothesis. They are not like puzzles of guessing games, which have a single correct answer. They are not like the problems of an artist or a composer, who works principally to satisfy self imposed goals and standards. Design problems often contain aspects of all these other types of problem, whilst remaining distinct. [145:99]

Two major steps make up the design process, as we know it today, the decision making stage and testing potential solutions to determine if they satisfy the requirements of the decision making stage (145:99). While a designer is performing design, he does not know if his solution will solve the client's requirements until he designs the building, and then checks the decision making stage (111:224). Therefore, the designer can not know what constitutes an adequate design until he designs it. The designer does not know all the new designs which can be derived from the present design; furthermore, trade-offs are hard to make. Further hindering the building design process, is the fact that the design belongs to two groups: that which is happening within the building (functional), and that which takes place outside (exterior context) (73:320). Now that we know the definition of design, we need to know the desired capabilities to satisfy the needs of the Technical Design Section.

At this moment, there are many opinions of the type of hardware and software that should be purchased for the Civil Engineering Community, but no one has ever really considered the users of this type of system. The system should be tailored to the designers and draftsmen of the Technical Design Section.

Two major problems underlie the full utilization of CAD systems to improve productivity of base level Technical Design Sections and increase the quality of designs. First, what is the present level of technical ability of the personnel in base level Technical Design Sections, and secondly, what computer hardware and software would be appropriate to increase productivity/quality of design and drafting in the Technical Design Sections? Furthermore, if the personnel have the technical ability, one must look at appropriate hardware and software from a "total computer system" implementation point of view.

According to Keen and Morton in their book entitled Decision Support Systems: An Organizational Perspective, several areas must be addressed to bring automated systems to an existing organization: 1) which alternatives offer the most improvement to the existing process; 2) how will the change be implemented; and 3) what happens if the system falls behind schedule or meets resistance (74:176). To deal with these possible problems, one must look at suspected problem areas in the initial planning stages. Furthermore, one needs to determine a plan for implementation of new automated systems which can serve also as a basis for designing the new automated system. There must be a "felt need" for the change, the user must play a part in the design and implementation, and the person who designs the system must be knowledgeable of the area he is designing for (74:205). Specifically, Keen and Morton see the following as part of the implementation phase of an incoming computer:

1. A felt need.
    a. The implementor must make sure that the problem to be worked on is visible and seen as relevant.
    b. The implementor must make sure that the client has a motive and commitment for action.
2. Definition of goals in operational terms.
    a. Determine the criteria for success.
    b. Determine the priorities and trade-offs.
    c. Determine "key indicators" which can be used to measure progress and accomplishment.

3. A contract for change. This involves a "deal" between designer and client that establishes:
   a. "Trust" which is built on a personal, professional, or political basis.
   b. Mutual understanding.
   c. Mutual respect for each other's style, investment and needs.
   d. Realistic, mutual expectations.
4. Diagnosis and resolution of resistance to change. This involves:
   **a. Including all users, as well as the client, in implementation. (Designers often ignore the secondary users, groups who are indirectly affected by the system, such as the people responsible for collecting certain input data)
5. Initial allocation of resources and responsibilities. This involves:
   a. Meaningful user involvement.
   b. The development of a team. [74:203]

**Client and users would be designers and draftsmen in the Technical Design Section, while users from the other sections of the engineering branch and quite possibly the planning section from the operations branch, would be secondary users.

Organizational Background

According to Major General Clifton D. Wright, former Director of Engineering and Services, the new Civil Engineering mission statement is to, "Provide the necessary assets and skilled personnel to prepare and sustain global installations as stable platforms for the projection of aerospace power in peace and war" (66).

Furthermore, according to Air Force Regulation 85-10, Operation and Maintenance of Real Property, the primary mission of civil engineering activities is to acquire, construct, maintain and operate real property facilities, and provide related management, engineering and other support work and services (36:2).

The complex nature of the Civil Engineering responsibility requires several branches within the base level squadrons. These sections include Administrative, Military Family Housing, Financial Management, Fire Protection, Industrial Engineering, Operations, Readiness, and Engineering and Environmental Planning. Four sections comprise the Engineering and Environmental Planning Branch. These sections are: Construction Management, Environmental and Contract Planning, Real Property, and Technical Design.

The Technical Design Section has a variety of responsibilities. According to Air Force Regulation (AFR) 85-10, the Technical Design Section:

-prepares, coordinates and designs projects, including plans, specifications and cost estimates, for all work to be done by contract.
-develops architectural and engineering reports, including, but not limited to, economic and engineering justifications
-prepares Architect-Engineer (AE) statements of work and participates in the selection of AE services.
-provides architectural and engineering advice and assistance.
-prepares design criteria for projects to be designed by other agencies.
-performs corrosion surveys and utility leak surveys.
-prepares architectural and engineering drawings, miscellaneous charts, forms, maps, area surveys, and collects data to be incorporated in location maps, records and systems.
prepares and maintains record drawings.
-provides professional engineering guidance for improvement and application of energy systems.
-prepares economic analysis based on present worth techniques to determine a benefit/cost ratio for energy conservation projects.
-prepares and maintains the utility brochure. Reviews utility invoices and determines utility sales rates.
-reviews and develops the technical provisions of utility contracts and assists the procurement officer in negotiating utility contracts [56:23].

According to D.F. Sheldon, in his article entitled The Present State of the Art of Computer-Aided Draughting and Design, "the tasks which can be accomplished using CAD, include: design, analysis, synthesis, perform calculations, draughting, detail and assembly drawing, drawing updating and filing, cataloguing, parts listing" (127:173). "For a

CAD system of the mini-supercomputer type, productivity gains from 2:1 to 4:1 can be achieved after a four to six month learning programme" (127:173). Productivity, in this instance, is measured by the amount of working drawings produced.

Justification

There are two major justifications for this thesis. First, Civil Engineers at the Air Staff level have shown interest in this topic. They were concerned enough about this problem to submit a thesis topic suggestion form to AFIT/LS for a study of this type.

The second reason stems from the attainment of the Work Information Management System (WIMS) by the Air Force Civil Engineering community. The WIMS is designed to provide data processing and function as a management information system for the Civil Engineering community detached from the initial WIMS acquisition due to lack of funds (92:23). Currently the Air Force Computer Graphics Working Group (AFCGWG) has been set up to determine what type of Computer-Aided Design and Drafting system capabilities are needed by base level Civil Engineering Squadrons (155). This thesis will provide information to determine the hardware and software needs of designers and draftsmen in the Technical Design Section of a base level Civil Engineering Squadron.

Scope and Limitations

There were two limitations to this research:

1. Only the Computer-Aided Design and Drafting needs of the Technical Design Section at a base level Civil Engineering Squadron were analyzed.

2. Only military members who have worked or are working in design are surveyed.

Assumptions

1. Military members who have accomplished technical design know what tools they need to do design.

2. Civil Engineering is experiencing a loss of productivity/ quality of designs due to non-automation of their Technical Design Section.

3. Techniques and equipment of civilian and Department of Defense (DOD) design agencies can be assimilated by the Air Force Civil Engineering community.

4. CAD complements the way the Technical Design Section accomplishes design.

Research Objective

Given the present level of technical ability of Architects and Engineers in a Base Civil Engineering Technical Design Section, what Computer-Aided Design and Drafting hardware and software would be appropriate to increase the quantity and quality of designs.

Research Questions

1. To what extent do Civil Engineering Technical Design Sections have the expertise to accomplish designs currently being accomplished by civilian Architectural-Engineering firms?

2. What are the current design activities of Architects and Engineers at base level Civil Engineering?

3. What training (design, CAD, etc.) do Architects and

Engineers in a Civil Engineering Technical Design have?

4. In what areas could Air Force designers use help while accomplishing design?

5. How would Architects and Engineers use CAD?

6. What is the average size of a typical Civil Engineering Technical Design Section?

7. What is the scope (dollars, projects, number of drawings, hours) of design at a typical base level design section?

8. What is the scope (dollars projects, number of drawings, hours) of AE design at a typical base level design section?

9. What CAD systems are currently utilized by DOD organizations?

10. What CAD systems are currently utilized by civilian Architectural-Engineering firms?

II. Literature Review

Introduction

Computer systems to help in the formulation of building designs have passed through many stages during the past 15 years. First generation computer systems performed two dimensional drafting functions. Second generation systems had the capability to manage a database. Third generation systems first performed 3D models. Fourth generation systems include surface and solid modeling. Finally, the Fifth generation computer system is attempting to integrate the first four generations, as well as introduce "artificial intelligence" into these systems (129:11).

Before one can determine the best computer-aided system for design and drafting, one must know what the various computer aided systems have to offer.

Computer-Aided Design (CAD)

The objective of CAD is to improve both the quality of service and product. CAD allows the designer to perform quality control of a design by allowing more time to look at "what if" situations (154:496-497). A CAD system must have the capabilities to handle the following characteristics:

(1.) No well-defined solution - many alternatives should be explored.
(2.) Assessment of benefits (are) difficult objectively.
(3.) Essentially 3D. Geometric model supporting both graphics and other applications.
(4.) Group or individual use by professional designers.
(5.) Both regular and intermittent use patterns.
(6.) Requires manipulation of large quantities of attribute data for analyses. [151:209]

CAD is not concerned with productivity, since productivity of a computer system does not create a new product or increase the quality of an existing product (ie. building). CAD uses the computer to generate new ideas, not merely increase the speed of design drafting Furthermore, design itself is concerned with both analysis of individual parts of a building and the synthesis of these respective parts into a unified whole (144:19).

CAD must break the design problem into a program to analyze the problem which the design solution must solve. Alternative solutions must be generated and basic decisions must be made at the outset of the design (35:35). To accomplish this, information must be taken in and the data sorted into subsets so some sort of "intelligence" can help to make basic decisions.

This "intelligence" can be derived from "expert systems", which is a branch of artificial intelligence. Expert systems can place knowledge of a particular field into a computer program, which can help the designer simulate some degree of human reasoning and judgement (97:67). This reasoning would be in the form of specific "facts, general laws, rules for applying laws, rules to handle conflicts, (and) rules of thumb" (145:341).

Computer-Aided Drafting (CADr)

According to Skidmore, Owings and Merrill, one of the top 20 Architectural-Engineering firms in the United States, "computer-aided drafting addresses the wrong problem. Why would you spend $100,000 to make the least expensive draftsman in the firm more productive?" (41:142) The idea behind computer-aided design is to improve quality and control of design, not the accuracy of drawings. (41:142)

Furthermore, some vendors misrepresent productivity gained by using computer-aided drafting. Many design firms take over a year to equal the productivity level of manual drafting techniques. After the initial year, many firms do lower the overall percentage of time they spend on working drawings from 40% to 10% - 15%. But even though computer-aided drafting helps productivity in the long-run, it is doubtful whether it produced significant economy in comparison to the initial cash outlay (78:153).

From a conceptual point of view, computer-aided drafting is no more than a new drawing medium. Instead of having a pencil and paper, you have a stylus/cursor and digitizing tablet. The computer-aided drafting system lacks the ability to make a two dimensional image into any significant three dimensional output automatically, which can be evaluated. Even the abilities of the two dimensional system are limited; for instance, it is generally possible only to scale an object up or down or to stretch it in a particular direction. Such operations seem impressive at first, but are in fact only seldom useful because there is no selective control over which features of an object could be scaled (157:160). But, regardless of all this criticism of a computer-aided drafting system, this system is still the most utilized by design firms (157:160).

Computer-Aided Analysis (CAA)

Computer analysis programs prepared by software companies help visualize structural loading effects on buildings, as well as help the designer see how energy flows within buildings. Analysis programs can analyze building compliance with energy, handicap, and fire codes. These computer analysis programs only supplement the manual design process. Analysis programs, as we know them today, are only automated versions of manually accepted procedures. Since these programs are only extensions of existing manual methods, these analysis programs cannot take dynamic and time-dependent variables into account (78:149).

Finally, the computer analysis program contains many one-of a-kind programs. One program designs floorplans and allocates spaces. Other computer programs help the architect or engineer compute costs, write specifications, schedule projects, and handle information (78:155).

Computer Modeling (CM)

Computer modeling goes beyond interactive (user-friendly) computer systems by actually aiding in the design process. In computer modeling, computer programs can be written to completely describe a building. By holding all elements constant, except one, the designer can optimize the results of different alternatives

> a parametric model, that is, one on which adjustments can be affected by changing just one number or a relationship...An intelligent computer model of a structure is not just a three-dimensional drawing, but a representation of the essential elements and internal relationships of a system that allows relevant manipulations and "what if" explorations to be performed easily. [157:159]

The ability to analyze results of a specific design is the objective of Computer-Aided Design/Computer-Aided Manufacturing (CADCAM). CADCAM is the predecessor to all CAD systems for building design. According to Arthur Llwelyn, from an article in the journal Computer-Aided Design, the intent of CADCAM is to introduce new possibilities using typical data. CADCAM can create realistic scenarios and test them by simulation using stored information. After testing, changes can be made rapidly to weed out problems (84:172).

Specifically, according to Dr. Christos Tountes of Columbia University, computer models which are written in procedural languages (FORTRAN,PASCAL) make full use of a computer's capabilities. With this type of system, models can be built in the preliminary design stage to test alternatives When these models yield satisfactory results, the information can be output in any format required: elevations, perspectives, plans. If upon further study, you find the preliminary design will not work, you can go back and change a parameter (in the computer program) and all drawings will be redrawn with changes (157:160).

The Architectural-Engineering firm at the forefront of computer-modeling is Skidmore, Owings and Merrill (SOM). SOM employs a group of architects and engineers, trained in computer programming, who write all their own computer-modeling programs. SOM's computer system "Workbench" ties together all aspects of the design process: sketching, design development, presentation, and contract drawings. SOM familiarizes their employees with the computer, because SOM believes it to be a powerful tool in the design process All the information collected and optimized to design the building then become a permanent record for that building. With this knowledge, future owners and users will be better able to repair and maintain the building (41:145).

A similar appraisal of computer modeling is expressed by John Lansdown, a well known computer-designer "...because detailed appraisal without the aid of computers is such a difficult and time-consuming process, it is rarely done in the very early design stages when formative decisions are being made and its results would be the most beneficial" (78:148). Models are predictive; whereas, plans and elevations are descriptive. Models permit the designer to continuously know the effect of a design on cost and performance. Not only does computer-modeling improve the designers ability to solve problems by checking solutions against one another, but it also improves other aspects of the design environment. One improvement resulting from the use of computer-modeling is a better working relationship between members of the design team. A great deal of time is lost while designs are passed between the members of a design team. Design members do not have to share the same office, since all information can be transported via computer modem. Using modeling, all members know what the design looks like at every moment (78:149).

Another improvement, is the ability to check a preliminary design against predetermined criteria which was set at the beginning of the design process. This enables the computer-model to distinguish between objective and subjective criteria; therefore, necessary value judgements become increasingly visible (78:149).

Beyond all the modeling and estimating abilities of the computer-modeling technique, the system is less expensive than an interactive (ie,"user-friendly") system. The reason it is less expensive is a parametric system does not need the hardware or software of a "user-friendly" system to produce computer-models. But, when architects and engineers realize that computer-models provide the greatest flexibility in optimizing design alternatives, the term "user-friendly" may be redefined (157:160).

Civilian Computer-Aided Systems

One possible way to determine what computer-aided design (CAD) systems may be responsive to the needs of an organization is to look at other firms and what they are accomplishing with computer-aided systems. This section will tell of individual experiences of firms, by firm.

Bobrow/Thomas and Associates (BTA), is a 100 person firm which specializes in health care, institutional and high technology in the US and abroad. BTA utilizes GDS Software with three dimensional (3D) capabilities. BTA utilizes their CAD system for schematic design, design development, and final working drawings. BTA believes the following increases are realized: productivity, accuracy, clarity, design alternatives, revisions, 3D study alternatives, standardization, and the ability to hold drawings for future remodeling (104:28).

Bohm-NBBJ is a national Architectural-Engineering firm using the Sigma III CADD system. Bohm uses their computer-aided design system for drafting, 3D modelling, space planning. They feel their system is especially useful for planwork, and creating larger scale enlargements from existing drawings (104:37).

The Everett I. Brown Company is a national full service Architectural and Engineering (AE) firm with a staff of over 400 people. EI Brown uses an Intergraph computer system in every design discipline area, architecture, civil/structural engineering, electrical engineering, and mechanical engineering. EI Brown works a great deal in the military design area, recently completing 54 standard designs for the Army Corps of Engineers (COE) (112:566). EI Brown utilizes the CAD system to increase building alternatives, analyais, drafting material take-offs, and cost estimating (104:65).

The Callison Partnership is a national architectural company with 120 professionals on staff. Callison uses four Calcomp workstations linked to a central processor. All peripherals are Calcomp. Callison uses the computer system for scheduling projects, design studies, and drafting (104:78).

The Carlson Group is a design-build firm. The Carlson Group uses Intergraph computer systems with a Hewlett-Packard 36" Pen Plotter; Engineering Production Drawing Package (EPDP); Architectural Modelling; Plant Design, piping, structural, and equipment modelling. The Carlson Group uses their computer system for drafting, and schematic design drawings. Most importantly, the Carlson structural section uses the CAD system to generate repetitive engineering plans. These plans, in the past, took about a week to design and draft, but now these designs take less than one day to complete (104:119).

Department of Defense Computer-Aided Systems

The Army Corps of Engineers uses a mainframe computer to run analysis programs. Some COE offices have a mainframe computer on the premises, while other offices utilize modems to patch into these mainframes from remote sites. Some of the analysis programs, with their specific design specializations, are: architecural (SEARCH- Systematic Evaluation of Architectural Criteria); civil (EARTHWORK);

structural (STRUDL- Structural Design Loads); mechanical (BLAST- Building Loads Analysis and Systems Thermodynamics); electrical (LIGHTING); quantities (TAKEOFF) (135:434). Furthermore, the Corps of Engineers (COE) uses computer-aided systems for both layout and documentation with the intent of getting the designer to design on the computer-aided system, instead of designing on paper and then placing the design onto the system (64).

The specific system the COE uses was designed in-house, it is called the Computer-Aided Engineering and Architectural Design System (CAEADS) and it is currently being used at all COE offices. Currently, the COE at their Construction Engineering Research Laboratory (CERL), Champaign, Illinois, in conjunction with EI Brown Architectural-Engineering firm, is attempting to design a true CAD system, which will serve as a design system to be utilized with the "AutoCAD" drafting system. The special innovation of this CAD system will be its manipulation by a hand-held mouse similar to the type used by an Apple computer. This ability will allow the designer to use stretching "rubber-banded" lines to sketch more freely, thus allowing the designer to "brain-storm" (13).

The Naval Facilities Command (NAVFAC) uses Computervision mini-based computers at all NAVFAC installations. This computer system provides the backbone of the Navy's Graphics Design System (GDS). NAVFAC uses this system to design in house and to check civilian AE work (22:495).

The Coast Guard does not have any computer-aided systems, however it is writing contracts with the provision that AE's use CAD. When the time comes to computerize, the Coast Guard feels, it will be in a position to utilize this computerized information provided by the AE's (22:495).

The Air Force has many types of computers at work in many different locations. The Integrated Graphics System (IGS) is the Air Force's program to bring computers on board. The IGS is being developed by the Air Force Computer Graphics Working Group, which is headed by Mr. Phil Clark HQ USAF/LEEV (26).

The Air Force Logistics Command undertook a CAD Feasibility Study in 1983. It was determined during this survey that a computer-aided design and drafting system was both feasible and justified at all AFLC Civil Engineering offices. Justifications included higher productivity rates and a centralized database, when utilizing a CAD system as a design, drafting, and data management source. This CAD system should be in place by December 1986 (137:5).

The largest project to date in the Air Force is the operation of 10 Intergraph work stations at the San Antonio Real Property Maintenance Agency (SARPMA) in an attempt to produce more in-house design and eliminate the use of civilian Architectural-Engineering firms. This system is entitled ADAM for Automated Drafting and Maintenance. The personnel at SARPMA feel they can reduce overtime and AE contract fees by 40% with the CAD system (27:1-4).

The Air Force Academy Civil Engineering Department uses AT&T micro-computers with AutoCAD software to teach both Community Planning and structural courses (156).

The Design Division Directorate of the Aeronautical Systems Division (ASD) has five Hewlett-Packard computers with VersaCAD drafting software. According to Lt. George Connor (a designer for the Directorate) the CAD system has improved the quality of the drawings (looks, accuracy) and provided uniformity and standardization. The Design Directorate personnel now use many standard details which were created on the CAD system. The CAD system allows these details to be saved, and used many times over to accelerate design rates (33:51).

Finally, Air Force personnel at Chanute AFB and researchers from the University of Illinois are experimenting with down-loading large mini and mainframe computer files to micro-computers via a translator. Up to this time, large mainframe or mini computers were required to manipulate large format drawings. If this test is successful, then the Air Force could use micro-computers to manipulate drawings which were originally constructed on a larger computer system. This would be especially helpful at those bases where Comprehensive Plans are being accomplished, by contract, in a CAD medium (10).

Selecting a Computer System

Selecting a computer system must begin with a feasibility study. According to Stanley Port in Computer-Aided Design for Construction, this study should aim to:

> Seek more background information on CAD.
> To identify applications which might benefit from the use of CAD methods.
> To consider the potential benefits to the organization.
> To determine the main options available.
> To draw up a list of those factors which will govern the choice of system - the selection criteria.
> To draw up a list of possible suppliers.
> To study individual systems.
> To plan for the introduction and management of the system. [109:95]

Within Stanley's feasibility study is the notion that one must know what factors to grade a system on. Some requirements may be:

> Supplier having knowledge of construction industry.
> System with construction industry 'feel'.
> Upgrade potential in hardware.
> Good drawing efficiency.
> Three-dimensional modelling.
> Supplier active in research and development.
> Supplier with good reputation and apparent stability.
> System able to cope with several large projects.
> Many systems already in use elsewhere.
> Existing users obviously satisfied with system.
> Good training facilities.
> Easy to use.
> Many facilities in system.
> Low cost. [109:95]

With this general overview obtained, one can then look at specific numbers of hardware (workstations) needed for the particular design section involved.

To determine the number of hardware peripherals needed, one needs to determine the number of drawings produced per year. After determining the hours of design/drafting per drawing, one can reduce that amount by the increased productivity of a CAD system. The increased productivity for CAD is currently considered to be between 2:1 to 3:1 per drawing. After determining the computer-aided design and drafting hours per drawing, one can divide this number by the total drafting time per draftsmen available to determine the number of workstations needed (137:3.25).

III. Methodology

Introduction

In this chapter, the specific methods used to answer the research questions from Chapter 1 are discussed. The research objective was to determine the present level of technical ability of Architects and Engineers in a Base Civil Engineering Technical Design Section, and to determine what Computer-Aided Design and Drafting hardware and software would be appropriate to increase the quantity of designs. These research questions needed to be answered to answer the "total" research objective:

1. To what extent do Civil Engineering Technical Design Sections have the expertise to accomplish designs currently being completed by civilian Architectural-Engineering firms?

2. What are the current design activities of Architects and Engineers at base level Civil Engineering?

3. What training (design, CAD, etc.) do Architects and Engineers in a Civil Engineering Technical Design Section have?

4. In what areas could Air Force designers use help while accomplishing design?

5. How would Architects and Engineers use CAD?

6. What is the average size of a Civil Engineering Technical Design Section?

7. What is the scope (dollars, projects, number of drawings, hours) of design at a typical base level design section?

8. What is the scope (dollars, projects, number of drawings, hours) of AE design at a typical base level design section.

9. What CAD systems are currently utilized by DOD military organizations?

10. What CAD systems are currently utilized by civilian Architecture-Engineering firms?

Justification of Approach

This research was aimed at designers in the Base Civil Engineering Technical Design Section. Although Air Force Logistics Command had completed a study to determine Computer-Aided Design and Drafting hardware needs for its bases, the Civil Engineering community Computer-Aided Design (CAD) software and hardware needs have not been determined.

This led to the necessity of surveying the current and near-current designers to determine which design areas might be improved by using CAD.

It could be hypothesized that an examination of current CAD hardware and software of DOD design organizations and civilian AE firms should lead to a list of CAD hardware and software for Air Force Base Civil Engineering Technical Design Sections. This author believed that Air Force Civil Engineering Design is unique to warrant determination and validation of CAD hardware and software needs. Therefore, a questionnaire was used to determine CAD hardware and software needs of the Base Civil Engineering Technical Design Section

Population of Concern

The author chose to perform a census of Continental United States (CONUS) officers with the following duty Air Force Specialty Codes (AFSC) and suffixes: 5521 A, C, E, F, G, or 5525 A, C, E, F, G. The population was limited to Second Lieutenant up through Lieutenant Colonel to guarantee relative currency in the design area. Those individuals who had never performed design tasks would be excluded by initial questions on the survey.

This population was chosen to obtain current knowledge of design practices and procedures. The author believed that significant user input could be obtained since this survey population was the theoretical end user of any system it prescribed.

The census was limited to military personnel at CONUS installations. This was due, first, to unacceptable labor union delays in approving the survey for civilians. Second, overseas locations need to be reviewed differently due to unique requirements. Finally, this research dealt with attitudes and perceptions of the design process and problems and there was no reason to believe that civilian responses would be significantly different from military responses

Survey Instruments

Two survey questionnaires and a telephone survey were utilized to collect data to answer the research questions. The proposed surveys were pretested to insure accurateness and conciseness and provide an estimate of the time required to complete the curveys. Twenty-seven of the questionnaires were distributed to the 86S Graduate Engineering Management (GEM) section and three were distributed to the members of the advising team of this thesis. Pretest evaluation identified several areas where changes were needed. These changes were incorporated into both surveys. The survey questionaire was sent to the Personnel Survey Branch, Air Force Manpower and Personnel Center (AFMPC) on 29 April 1986 for approval. The approved questionnaire, with changes, was given USAF survey control number 85-65, expiring 31 July 1986. The first surveys were mailed to the CONUS survey population on 1 June 1986. The second survey was mailed to all Chiefs of Engineering and Environmental Planning in CONUS and asked for specific design information, not opinions. This survey was mailed out 24 June 1986, since the lack of response made the phone survey impossible.

The first survey questionaire (Appendix A) consisted of five sections. Section I included background information (demographic) questions. This information was used to screen the population to make sure the respondents had worked as designers. Furthermore, this section provided information which could break out specific subpopulations which could be compared to each other to provide a better picture of the overall population. Finally, this section provided a transition for the respondent into the data collection parts of the survey.

Section two of the questionaire contained two specific questions to determine numbers of military and civilian designers and draftsmen in the Technical Design Section. This section helped answer research question 6. This data was used to determine CAD hardware needs based upon numbers of personnel who would utilize the equipment.

Section three dealt with questions of training and the capability of the designer to accomplish a design project satisfactorily. This section contributed information to answer research question 3.

Section four contained 27 questions which were concerned with how an individual wanted to design, problems encountered in the design process, and particular areas of design. This section contributed to research question two and four.

Section five analyzed the types of work the architect or engineer accomplished by way of a rank ordering of typical design tasks; furthermore, the section identified the amount of time spent accomplishing these tasks. Finally, this section asked three open-ended questions on types of analysis/calculations used in design, how this individual perceived the use of CAD in civil engineering design and if he had any experience with CAD. This section also helped answer research questions 2, 3, 4, and 5.

The second survey was used to determine the dollar amount and numbers of projects designed in-house and by AE

(Appendix A). Furthermore, this information was obtained while knowing the size of the base military and civilian populations to be able to separate these different subpopulations to determine if computer-aided hardware needs were different at various sized bases. This survey, which was posed to the Chief of the Engineering and Environmental Planning Branch, asked if the Technical Design Section was not doing projects because they did not have the expertise to design, or did the designers just not have the time. This information would be combined with the Air Force Logistics Command CAD survey information to determine the quantities of computer workstations required. This information helped answer research questions 1, 6, 7, and and 8.

Questions 9 and 10 were answered in the literature review, except that some answers CAD utilization were brought out in section V of the first survey.

Analysis

Survey responses were coded and input into the AFIT ASC computer system. The Statistical Package for the Social Sciences (SPSS) was utilized to determine frequencies of responses and means using ANOVA, CROSSTABS, and FREQUENCY subprograms.

The ANOVA subprogram was used to show where differences in the means occurred among the groups (specialization, time as a designer, in/out of design, major command, first assignment) and also led to an affirmative or negative response to the question. The hypothesis tested for each subject area was the following

H_o (null hypothesis) $u < 2.5$

H_a (alternate hypothesis) $u > 2.5$

at a significance level of .05. Those questions which were answered with a response of equal to or greater than 2.5 and were statistically significant were judged affirmative. Those answers less than 2.5 were negative responses. Answers statistically significant, were judged as negative responses, even though they may have been true.

The data was then compared by specialization, time worked as a designer, and last time as a designer to determine variances in responses. This information helped answer questions 2, 3, 4, and 5.

IV. Presentation of Data

Survey Results

This section presents the data collected during the design and project data surveys. 915 design surveys were sent out to CONUS officers and 497 surveys were returned, which makes the return rate approximately 54%. Of the 497 surveys returned, 306 of the officers had performed design in a base level design section, 16 were received after the cutoff date of 27 June 1986, 153 officers had never performed design, 7 surveys were not useable, and 15 surveys were returned without sufficient mailing addresses.

With this information, the survey population was lowered to 762 officers, since 153 officers had never performed design. Using the results of the survey, an average standard deviation of 1.01 was obtained for the survey questions. This information with the size of population (762) and the sample size (306) were placed in the appropriate equation to obtain the confidence level of the survey sample. The standard deviation was determined to be 1.01, since this was the actual average standard deviation of all questions asked in the survey. The standard error was .045 which gives a confidence level of 95.5% certainty.

$$\text{standard error} = [s/(n-1)^{1/2}] \times [(N-n)/(N-1)]^{1/2}$$

s = standard deviation
N = size of population
n = size of sample

$$\text{standard error} = [1.01/(306-1)^{1/2}] \times [(762-306)/(762-1)]^{1/2}$$

$$= .045$$

Of the 87 project data surveys sent to the Chief of the Engineering and Environmental Planning Branch at each base, only 30 were returned. With the sample size of only 30, the central limit theorem can be utilized to say that the results are representative of all CONUS bases. Unfortunately, differences between large, medium, and small sample sizes can not be determined with any statistical certainty.

Design Survey

The frequency of demographic questions and means of scaled questions are presented in the following design survey format:

Table 4.1

Background Information Results

1. Have you ever worked in the Technical Design Section as a designer?

306 Yes 152 No

2. Are you a commissioned Air Force officer?

306 Yes 1 No

3. What is your current rank?

87 Second Lieutenant 114 Captain
100 First Lieutenant 3 Major

4. Years of commissioned service?

7 Less than 6 months 56 3 to 4 years
34 6 months to 1 year 39 Less than 6 years
42 1 to 2 years 83 Greater than 6 years
44 2 to 3 years

5. How long have you worked or did you work as a designer in the Technical Design Section?

14 Less than 6 months 49 3 to 4 years
82 6 months to 1 year 8 Less than 6 years
85 1 to 2 years 2 Greater than 6 years
65 2 to 3 years 0 Never worked as a designer

6. If you are not presently working as a designer, when was the last time you worked as a designer?

48 Less than 6 months 27 3 to 4 years
20 6 months to 1 year 20 Less than 6 years
30 1 to 2 years 15 Greater than 6 years
28 2 to 3 years 114 In Design

7. Is this your first assignment as a commissioned officer?

166 Yes 136 No

8. What Major Command do you work for?

33	ATC	7	SPACECMD
0	AAC	77	SAC
30	AFLC	67	TAC
19	AFSC	46	Other
24	MAC		

9. What is your area of specialization?

65	Architect	0	Industrial Engineer
120	Civil Engineer	60	Mechanical Engineer
49	Electrical Engineer	11	Other

10. What is your present level of assignment?

10	Air Staff Level	216	Base Level
43	Major Command Level	34	Other

11. How many architects and engineers accomplish design in the Technical Design Section?

12. How many draftsmen accomplish drafting for the Technical Design Section?

The information from questions 11 and 12 was not used, because the data obtained would not be representative of design sections. For example, three officers from one base may have responded to the survey and each would have the same data for questions 11 and 12. This information, since not just one answer for the specific CONUS base was given, could be skewed—the total outcome either higher or lower than what the actual answer should be.

Table 4.2

Training Results

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
0	1	2	3	4

13. I feel I've received proper on-the job training to accomplish my job.

1.712 (Note: This is the mean rating.)

14. The information/ knowledge I receive from attending AFIT courses is an important source of information to accomplish design.

3.040* (Note: * significant at the .05 level.)

15. The information/ knowledge I receive from self-learning is an important source of information to accomplish design.

3.374*

16. The information/ knowledge I receive from senior civilian architects or engineers is an important source of information to accomplish design.

3.053*

17. The information/ knowledge I receive from my supervisor is an important source of information to accomplish design.

2.278

18. The information/ knowledge I receive from my peers is an important source of information to accomplish design.

2.944*

19. I feel capable of performing design.

3.079*

Table 4.3

Design Results

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
0	1	2	3	4

20. My design projects are always adequately developed.

2.484 (Note: This is the mean rating.)

21. I look at adequate numbers of design alternatives to make the best design decisions.

2.611* (Note: * significant at the .05 level.)

22. I would like to look at more design alternatives in future design projects.

2.944*

23. I feel it essential to understand what my design looks like in three dimensions.

2.803*

24. I use three dimensional models in solving design problems.

1.418

25. I would like to use 3D models in my design analysis.

2.650*

26. I always rely on as-built drawings, as is. They are very reliable, and do not need to be verified.

0.325

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
0	1	2	3	4

27. I always go out and check as-built drawings against existing conditions before attempting a design.

3.379* (Note: This is the mean rating.)

28. I always send someone out to check as-built drawings against existing conditions before attempting a design.

1.636 (Note: * significant at the .05 level.)

29. I have a difficult time cross-checking all drawings and specifications.

2.086

30. I spend a great deal of time cross-checking drawings and specifications.

2.591

31. I would like more time to cross - check drawings and specifications.

2.651*

32. I generally do most of my own drafting.

1.425

33. I would like to do more drafting of contract drawings.

1.608

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
0	1	2	3	4

34. Most of my designs are cut and pasted from existing building design documents.

1.751 (Note: This is the mean rating.)

35. I would like to get away from having to cut and paste designs.

2.693* (Note: * *significant at the* .05 level.)

36. I always have plenty of time to accomplish design projects

0.889

37. If I had more time, I could produce a better design.

3.158*

38. I spend a great deal of time managing designs completed by an Architectural-Engineering firm.

2.467

39. I spend a great deal of time managing in-house design projects.

2.253

40. I complete many calculations while accomplishing design.

2.518

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
0	1	2	3	4

41. I have a difficult time cross-referencing all drawings.

1.818 (Note: This is the mean rating.)

42. I can rely upon all drawings accomplished by draftsmen being error free.

0.385

43. I spend a great deal of time determining the "concept" or approach to a specific design.

2.145

44. I spend a great deal of time checking codes which apply to my design.

2.195

45. I accomplish enough cost estimates to have a handle on construction costs at all times.

1.947

46. The Technical Design Section I work in manages design of projects satisfactorily.

2.139

47. I am satisfied with the technology available to accomplish design in my Technical Design Section.

1.314

Table 4.4

Existing Work Rating and Open-Ended Questions

	MOST TIME <———					———> LEAST TIME	
Number Ranking	0	1	2	3	4	5	6	NEVER ACCOMPLISH
Letter Response	A	B	C	D	E	F	G	H

53. Specifications--1.973 (Note: This is the mean rating.)

51. Project Management (AE or in-house)--2.324

50. Design Analysis/Calculations--2.427

54. Working Drawings--2.433

52. Schematic Design (Initial layout of a design)--2.735

49. Cost Estimating--2.956

48. Code Checks--4.031

55. What percentage of your total weekly work time do you spend accomplishing the tasks above?

10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	1	2	3	4	5	6	7	8	9

5.229 or 62.29% of their time is spent on design.

56. What types of design analysis and/or calculations do you accomplish while designing?

(See Appendix D)

57. Are any of these analysis/calculations computer based?

<u>33</u> Yes <u>234</u> No

58. If YES to question 57, what types of computer hardware/ software do you use?

(See Appendix E)

59. In what ways do you believe a computer-aided design and drafting system could improve production and quality of designs of the Technical Design Section? How would you use this system? Please use the back of the sheet if you need more room.

(See Appendix F)

60. List any training or experience you have with computer aided design and drafting systems. Please use the back of the sheet, if you need more room.

(See Appendix G)

Project Data Survey

Mean values of personnel and dollar amounts obtained by the project data survey are contained in Table 4.5:

TABLE 4.5

Mean Values of Design Work for Three Base Sizes

Base Size/no.	Year	In-House Projects no./dollar	AE Design Projects no./dollar	Designer civ/mil		Drafting civ/mil	
Small/4	1984	34/ 5.40	a. 6/2.83 b. 1/0.69 c. 0/0.00	5	4	1	4
	1985	40/ 7.28	a. 9/3.24 b. 1/0.22 c. 0/0.00				
Medium/18	1984	56/10.33	a. 9/2.56 b. 1/0.30 c. 0/0.00	7	5	1	7
	1985	65/10.64	a.11/3.07 b. 1/0.15 c. 0/0.00				
Large/8	1984	111/18.38	a.25/5.26 b. 6/1.77 c. 1/0.08	18	4	2	7
	1985	127/22.40	a.28/6.62 b. 6/1.74 c. 1/0.13				
Mean/30	1984	67/11.37	a.13/3.55 b. 3/0.75 c. 1/0.03	10	4	1	6
	1985	77/13.44	a.16/4.31 b. 3/0.70 c. 1/0.04				

Small <4000 base population
Medium 4000-8000 base population
Large >8000 base population
*Base population data from the May 1985 Air Force Magazine.
a. Technical Design Section did not have the time/manpower.
b. Technical Design Section did not have the expertise.
c. Other reason for not designing in-house.

Air Force Logistics Command (AFLC) Design Data

The following data was compiled from the 1983 AFLC CAD Survey.

TABLE 4.6

Design Data from AFLC Bases

Base	Hours	In-House Drawings	AE Design Drawings	Designer civ/mil		Drafting civ/mil	
Hill AFB		328	242	29	4	0	11
	a. 13,849						
	b. 5,985						
	c. 57,126						
McClellan AFB		1297	578	31	1	3	9
	a. 32,225						
	b. 26,000						
	c. 70,735						
Robins AFB		356	271	26	4	0	7
	a. 17,418						
	b. 17,964						
	c. 49,578						
Tinker AFB		618	268	22	3	0	10
	a. 9,501						
	b. 7,884						
	c. 42,935						
Wright-Patterson AFB		2375	325	47	8	1	9
	a. 30,239						
	b. 24,465						
	c. 74,256						
Average AFLC AFB		1095	337	31	4	1	9
	a. 20,646						
	b. 16,420						
	c. 58,926						

a. Drafting, b. Design, c. Other.

V. Analysis of Data

Introduction

In this section, analyses of the literature review and survey data are provided. The analyses are tailored to each research question.

Research Question One

TO WHAT EXTENT DO CIVIL ENGINEERING TECHNICAL DESIGN SECTIONS HAVE THE EXPERTISE TO ACCOMPLISH DESIGNS CURRENTLY BEING ACCOMPLISHED BY CIVILIAN ARCHITECTURAL-ENGINEERING FIRMS?

From the results of the survey given to the Chief of the Engineering and Environmental Planning Branch at each CONUS base, the average base designs approximately five million dollars worth of projects by AE. Of these figures for the last two years, 800 thousand dollars per year is spent because the design section does not have the expertise to accomplish the design.

Clearly, if the CONUS base design sections had the time they could design 4/5 of all design now accomplished by AE firm. Most importantly, calculating the AE fee based on the usual 6% rate, each CONUS base could save 240 thousand dollars per year in AE fees.

Research Question Two

WHAT ARE THE CURRENT DESIGN ACTIVITIES OF ARCHITECTS AND ENGINEERS AT BASE LEVEL CIVIL ENGINEERING?

Current designers in base level design positions spend approximately 62% percent of their time accomplishing tasks which are directly related to the design process or construction of design complete projects.

Initially, the new designer (less than one year) spends most of his/her time accomplishing project management (Table 5.1), which may show a lack of introduction to the new work area. After the one year mark, designers spend most of their time concerned with specifications and working drawings After the working drawings and specifications, in order of time spent, come analysis/calculations, project management, schematic design, cost estimating, and code checks. Project management begins to be a more predominant occupation between the 2 to 4 year period (Table 5.2).

Looking at differences in specializations, architects tend to be project managers, and use more of their time developing cost estimates than the other three engineering disciplines (Table 5.3). Mechanical engineers and electrical engineers tend to produce many more calculations than either the architect or civil engineer (Table 5.4). There is no difference between those officers currently in design, and those who have previously accomplished design.

TABLE 5.1

Rank Order of Questions by Current Designers by Time as a Designer

	6m-1y	1y-2y	Combined
%Time	66.56	60.00	63.24
Most	51 PM	54 WD	53 SP
	53 SP	53 SP	54 WD
	54 WD	50 DC	51 PM
	50 DC	51 PM	50 DC
	52 SD	52 SD	52 SD
	49 CE	49 CE	49 CE
Least	48 CC	48 CC	48 CC

Survey Questions

48 CC-Code Checks

49 CE-Cost Estimating

50 DC-Design Analysis/Calculations

51 PM-Project Management (AE or in house)

52 SD-Schematic Design (Initial layout of a design)

53 SP-Specifications

54 WD-Working Drawings

TABLE 5.2

Rank Order of Questions by Time as a Designer

	6m-1y	1y-2y	2y-3y	3y-4y
%Time	64.29	63.26	61.17	67.75
Most	51 PM	53 SP	51 PM*	54 WD
	53 SP	54 WD	53 SP*	51 PM
	54 WD	51 PM	54 WD	53 SP
	50 DC	50 DC	50 DC	50 DC
	52 SD	52 SD	52 SD	52 SD
	49 CE	49 CE	49 CE	49 CE
Least	48 CC	48 CC	48 CC	48 CC

Survey Questions

48 CC-Code Checks

49 CE Cost Estimating

50 DC Design Analysis/Calculations

51 PM-Project Management (AE or in-house)

52 SD Schematic Design (Initial layout of a design)

53 SP-Specifications

54 WD-Working Drawings

* tie

TABLE 5.3

Rank Order of Questions by Current Designers by Specialty

	Arch	Civil	Combined
%Time	67.67	65.14	63.24
Most	51 PM	53 SP	53 SP
	54 WD	54 WD	54 WD
	53 SP	51 PM	51 PM
	52 SD	50 DC	50 DC
	49 CE	52 SD	52 SD
	50 DC	49 CE	49 CE
Least	48 CC	48 CC	48 CC

Survey Questions

48 CC-Code Checks

49 CE-Cost Estimating

50 DC-Design Analysis/Calculations

51 PM-Project Management (AE or in-house)

52 SD-Schematic Design (Initial layout of a design)

53 SP-Specifications

54 WD-Working Drawings

TABLE 5.4

Rank Order of Questions by Specialty

	Arch	Civil	Elec	Mech
%Time	63.75	63.06	59.58	61.67
Most	51 PM	53 SP	50 DC	50 DC
	54 WD	54 WD	52 SD	51 PM
	53 SP	51 PM	53 SP	53 SP
	52 SD	50 DC	54 WD	54 WD
	49 CE	52 SD	51 PM	52 SD
	50 DC	49 CE	48 CC	49 CE
Least	48 CC	48 CC	49 CE	48 CC

Survey Questions

48 CC-Code Checks

49 CE-Cost Estimating

50 DC-Design Analysis/Calculations

51 PM-Project Management (AE or in-house)

52 SD-Schematic Design (Initial layout of a design)

53 SP-Specifications

54 WD-Working Drawings

Design Analysis/Calculations. After compiling all the analysis questions, these procedures were those most used by the designers. All areas with over ten responses are shown.

TABLE 5.5

Architectural Analysis/Calculations

1.	Structural Analysis (foundation,beam,column) 37
2.	Cost Estimating 24
3.	Architectural layout (space,circulation,flow,functional, bubble diagrams,user needs) 20
4.	Quantity take-offs 13
5.	Square footages 12
6.	Space allocation (utilization,requirements) 10
7.	Cost analysis (alternatives) 10

TABLE 5.6

Civil Analysis/Calculations

1.	Structural analysis (concrete,steel,wood) 30
2.	Concrete design (foundation walls,footing) 27
3.	Simple structural beams and columns 23
4.	Pavement capacity (analysis/design,flexible/rigid,sidewalks) 18

TABLE 5.7

Electrical Analysis/Calculations

1.	Load Calculations (circuit, maximum KVA, power) 27
2.	Lighting (levels, loads, alignment) 26
3.	Wire/Conductor sizing 16
4.	Short circuit analysis/fault current/ switch load analysis 11
5.	Motor/generator sizing 11

TABLE 5.8

Mechanical Analysis/Calculations

1.	Heating, ventilating and air conditioning (HVAC) load estimating 44
2.	HVAC duct sizing and design (cfm, static pressure, velocity, friction loss) 26
3.	Pipe sizing (plumbing, head, flowrate, pressure drop) 24
4.	HVAC equipment selection 14

Research Question Three

WHAT TRAINING (DESIGN, CAD, ETC.) DO ARCHITECTS AND ENGINEERS IN CIVIL ENGINEERING TECHNICAL DESIGN HAVE?

As we look at the sub-groups of those officers in design versus those officers in a combined group of designers and former designers, one finds that not all groups can be equally compared. For instance, when looking at specialties all four specialties (architect, civil, electrical and mechanical) are represented with more than 30 subjects. When looking at the design group, only architects and civil engineers can be looked at with any sort of significance, and even the architects do not have the requisite 30 samples to invoke the central limit theorem in every instance. So where findings look at mechanical and electrical engineers, these findings are from the entire population of officers who have accomplished design.

The first striking information from the two groups, is the fact that self-learning and senior civilian architects and engineers are in the one and two position, and for those officers who are currently doing design, the third and fourth places respectively are peer knowledge and AFIT (TABLE 5.9). Of those persons who have done design at one time, the list goes AFIT and then peer knowledge (TABLE 5.10). This may signify that there is a decrease in the importance of the AFIT role in training. None of the answers are significantly different from one another.

TABLE 5.9

Rank Order of Training by Current Designers by Specialty

	Arch	Civ	Combined
Most	15 SL	15 SL	15 SL
	16 SC	16 SC	16 SC
	18 PK	18 PK	18 PK
Least	-----	14 AF	14 AF

Survey Questions

14 AF-AFIT training

15 SL-Self-learning

16 SC Senior civilian architects or engineers

18 PK-Peer knowledge

* tie

-- inadequate survey population

Of those officers from the total population, there is a split where the designers are gaining information. This split has the architects and civil engineers on one side, and the electrical and mechanical engineers on the other side. Architects and civil engineers gain more of their information from self-learning and senior civilians, while mechanical engineers and electrical engineers depend more on self-learning and AFIT. This trend may be attributable to the fact that mechanical and electrical engineers deal with technology that changes at a faster pace than the methods used by architects and civil engineers (Table 5.10).

TABLE 5.10

Rank Order of Training by Specialty

	Arch	Civil	Elec	Mech
Most	16 SC	15 SL	14 AF*	14 AF
	15 SL	16 SC	15 SL*	15 SL
	18 PK	18 PK	18 PK	18 PK
Least	14 AF	14 AF	16 SC	16 SC

Survey Questions

14 AF-AFIT Training

15 SL-Self-learing

16 SC-Senior civilian architects or engineers

18 PK-Peer knowledge

* tie

When comparing the in-design group with the overall population, the only change is the fact that architects in design rely upon self-learning first, instead of senior civilians.

Looking at the two populations from length of time worked as a designer, AFIT rises as a learning device as the time worked as a designer increases, the importance of peer knowledge decreases, but self-learning is always the most important learning avenue. The only change seems to be in the reliance upon senior civilians. The total group ranks senior civilians as second, up to year two, then this group declines to third place. In the group which looks at only designers, senior civilians start in the third position. This seems to portray a lessening of reliance upon senior civilians. This could also show the lessening of senior civilian infuence, due to senior civilian retirements (Table 5.12)

TABLE 5.11

Rank Order of Training by Current Designer by Time as a Designer

	6m-1y	1y-2y	Combined
Most	15 SL	15 SL	15 SL
	18 PK	14 AF	16 SC
	16 SC	16 SC	18 PK
Least	14 AF	18 PK	14 AF

Survey Questions

14 AFIT training (AF)

15 Self-learning (SL)

16 Senior civilian architects and engineers (SC)

18 Peer knowledge (PK)

* tie

TABLE 5.12

Rank Order of Training by Time as a Designer

	6m-1y	1y-2y	2y-3y	3y-4y
Most	15 SL	15 SL	15 SL	15 SL
	16 SC	16 SC	14 AF	14 AF
	18 PK	14 AF	16 SC	16 SC
Least	14 AF	18 PK	18 PK	18 PK

Survey Questions

14 AFIT training (AF)

15 Self-learning (SL)

16 Senior civilian architects and engineers (SC)

18 Peer knowledge (PK)

* tie

<u>Prior CAD Experience</u>. Leaving the area of how design personnel were trained on the job, we looked at the training designers received in college or work prior to coming into the Air Force (Appendix G). This open-ended question asked for previous experience in CAD and many of the respondents identified the fact that they have had at least an introductory course in CAD or computer-aided analysis (Table 5.13).

TABLE 5.13

Prior CAD Experience

1.	Computer-Aided Design Experience 40
2.	Computer-Aided Analysis Experience 19
3.	Computer Language Experience 15
4.	Computer-Aided Design Demonstrations 7

CAD in the Design Section. Forty officers, currently in a base level Technical Design Section, now use computers of some type (Appendix E). This shows that there is currently interest in computers in the design section. This fact will help many others desire computers, since there seems to be a "felt" need for computers.

Research Question Four

IN WHAT AREAS COULD AIR FORCE DESIGNERS USE HELP WHILE ACCOMPLISHING DESIGN?

Specialties. This part of the question is answered using information contained in Appendix H. The mechanical and electrical engineers were without sufficient number to check their answers by designers only; therefore, these answers were combined with those officers who were not currently in a design position. The data allowed the examination of architects and civil engineers who were either in design, or by looking at a combined group of both those officers in design and those not in design. Comparing both the group of officers who are in design, and the combined group of designers and former designers, all officers feel they are capable of performing design. All designers believe that the technology available to perform design is not adequate. This seems to say that officers can perform design, but that designers wish to have better equipment to improve their designs.

When asked if their designs are adequately developed, and if they looked at enough design alternatives, only civil engineers currently in design said they looked at enough alternatives. All other groups, in design or not, said they did not look at enough alternatives. The strange thing, is that even the civil engineers agree that they need to look at more alternatives.

Architects and mechanical engineers believe it is essential to understand what a design looks like in three dimensions. In the case of the electrical engineers, they would not need the 3D, since they mostly deal with two dimensional schematic drawings, and for civil engineers, the possibility exists that many of these designers are dealing with pavements which would not need a three-dimensional viewpoint. Not one of the groups significantly uses 3D. Architects in both groups and mechanical engineers in the combined group would use three dimensional design, if they had the opportunity.

All groups significantly responded that they, themselves, checked as-builts. Furthermore, the reason all the groups went out to look at the buildings was because everyone believed the as-builts to be in bad shape. Likewise, all groups respond that draftsmen make errors.

Of all the groups surveyed, only the combined group of all past/present designers would like to have more time cross-checking drawings and specifications. None of the groups have a difficult time cross-checking, and none of the groups spend a great deal of time cross-checking. None of the groups have a problem cross-referencing drawings alone. One thing here is the possibility that all groups may be having problems, since the answers are greater than 2.5, but the answers are not significant at the .05 level.

None of the repondent groups do much drafting, and none of the groups would like to do more

None of the groups use mostly cut and paste design, but the architects in both groups, and the civil engineers in the combined group would like to get away from cut and paste design. The other groups (electrical, mechanical) would not like to stop using cut and paste methods. This included the combined civil engineer group. This may say that these groups wish to continue cutting and pasting, or they may not be doing it, and therefore would not have to get away from it.

None of the groups had enough time to do design, and they feel if they had more time, they could do a better design.

None of the groups spend a great deal of time managing either in-house or AE designs. On the other hand, all groups respond that design is not managed adequately in their respective design sections. This could lead one to believe that designers do not do management because they do not have the time.

None of the groups believe they complete many calculations.

None of the groups spend a great deal of time working on a concept for a project.

Electrical engineers in the combined group, are the only group which look at codes a great deal of time.

None of the groups do enough cost estimates.

Time in Design. The information to perform this analysis is contained in Appendix H. Current designers in the one to two year time period believe their projects are adequately developed and that they look at enough design alternative to make the correct design decision. All groups, even the aforementioned, believe they should look at more alternatives.

Designers (current) in the 1-2 year period, do not believe it essential to know what a design looks like in three dimensions, and they wouldn't use a 3D system. The 6 month to 1 year group and overall combined group would use 3D if they had the chance. The 1-2 year group of current designers is less than 2.5, so they would not want to use 3D. The possibility seems to exist that civil engineers do not want to use 3D later, since they have not been doing design while looking at buildings in a 3D mode.

Only the 6 month - 1 year and 2-3 year combined group would like to get away from cutting and pasting. All other group answers are greater than 2.5, but are not significant. This answer may affirm that many designs are cut and pasted from existing projects.

The 3-4 year group of the combined group spends a significant amount of time managing AE design.

Last Time in Design. This analysis is performed using data stored in Appendix H. None of the groups look at adequate numbers of alternatives, and the one to two year group would not like to look at more alternatives.

Only those officers in design, and those out of design less than six months, feel it essential to know 3D.

Those designers, who have been out of design less than six months, would like more time to check drawings and specifications. This may show that those just leaving design know that this is essential for good design.

Research Question Five

HOW WOULD ARCHITECTS AND ENGINEERS USE CAD?

A list of answers obtained from the design survey, follows in Table 5.14. All uses with over ten responses are shown:

TABLE 5.14

How Architects and Engineers would use CAD

1. Alternative/detailed design analysis 54
2. Calculations 53
3. Decrease drafting time 52
4. Update as-built (better) 47
5. Modify drawings quicker 43
6. Cut and paste repetitive jobs (detail) 37
7. Reduce design time (quality/direct usage) 31
8. 3D 30
9. Professional product (clean/standardized/QC) 30
10. Cost estimate (local information) 26
11. Specifications (standardized) 26
12. Reduce errors 21
13. Concept/schematic 16
14. Better design 15
15. CAD is not warranted for us 15
16. Find conflicts in design 14
17. Share information between designers 14
18. Intelligent/accessible (optimization) database 12
19. Reduce manning in drafting 10

Most of these uses (and why CAD is better) would be compatible to the way a Technical Design Section currently performs design and drafting tasks. Not until you get to seventeen and eighteen, do you start to see concepts that really are different from current design practice, and depending upon cost may not be accessible today.

<u>CAD Hardware Determination</u> Utilizing the information obtained in the AFLC CAD Survey, and the information received in the Project Data Survey, helped determine the amount of hardware necessary for a Technical Design Section. The data obtained in the AFLC survey is not significant beyond AFLC bases, but will be used. Data collected in the Project Data survey, can only determine an average Air Force Base, so any derived calculations showing small, medium, and large base sizes are not significant.

The hours available per draftsman, per year in the AFLC calculations is 2080 hours. This number portrays a forty hour week for 52 weeks. This author believed that this number should be decreased to include time for training and other non-drafting time. The hours were therefore lowered to 1560 (75%). This seems to be a somewhat more accurate time because even the designers (military) only spend 62% of their time completing design tasks.

CAD productivity in the AFLC survey was determined to be between 2:1 and 3:1, so a figure of 2.8:1 was calculated (137:3.25).

(Yearly Drafting Hours)/(Total Drawings) = [Hours per Drawing]

(Hours per Drawing)/(CAD Productivity) = [CAD Hours per Drawing]

$$\frac{\left[\text{Total Drawings}\right] \times \left[\text{CAD Hours per Drawings}\right]}{\left[\text{Drafting Hours per Year per Draftsmen}\right]} = \boxed{\text{Number of CAD Workstations Needed}}$$

1. Using 2080 hours per year.

(20,646)/(1095) = 18.855 hr/drawing

(18.855)/(2.8) = 6.734 CAD hr/drawing

(1095 x 6.734)/(2080) = **3.54 or approximately 4 workstations.**

2. Using 1560 hours per year.

(1095 x 6 734)/(1560) = **4.72 or approximately 5 workstations.**

Although design is not measured by productivity of drawings, CAD workstation numbers for the designers could be determined in this same manner.

3. Using 1560 hours per year.

(16,420)/(1095) = 14.995 hr/drawing

(14.995)/(2.8) = 5.356 CAD hr/drawing

(1095 x 5.356)/(1560) = **3.76 or approximately 4 workstations.**

4. Using 1290 (or 62%) hours per year.

(1095 x 5.356)/(1290) = **4.54 or approximately 5 workstations.**

The number of workstations could also be looked upon as having the same proportion of designers to CAD versus draftsmen to CAD. Working on this proposition, there are two draftsmen to every CAD system. This would necessitate two designers per CAD also.

Using one CAD workstation per every two designers and draftsmen, would necessitate the following hardware need:

TABLE 5.15

CAD Workstation Needs

Base Size	Design	Drafting	Total
Small	5	3	8
Medium	6	4	10
Large	11	5	16
Average	7	4	11

Research Question Six

WHAT IS THE AVERAGE SIZE OF A TYPICAL CIVIL ENGINEERING TECHNICAL DESIGN SECTION?

The average size Civil Engineering Technical Design section has ten civilian designers, 4 military designers, less than 1 civilian draftsperson, and 6 military draftsmen.

Research Question Seven

WHAT IS THE SCOPE (DOLLARS, PROJECTS, NUMBER OF DRAWINGS, HOURS) OF DESIGN AT A TYPICAL BASE LEVEL DESIGN SECTION?

During the 1984/1985 time frame, where these statistics were taken, the average CONUS base spent between 11.4 million dollars (1984) and 13.4 million dollars (1985). From this, we shall say that 12.4 million dollars are spent on the average CONUS Air Force Base. Furthermore, for this cash outlay the air base received approximately 72 design projects.

As to drawings, the average large size base (which is not statistically significant) produces 1095 contract drawings per year. To accomplish this feat, costs (on average) 20,646 drafting hours, 16,420 design hours and 58,926 hours spent on administration and management.

Research Question Eight

WHAT IS THE SCOPE (DOLLARS, PROJECTS, NUMBER OF DRAWINGS, HOURS) OF AE DESIGN AT A TYPICAL BASE LEVEL DESIGN SECTION?

The average CONUS base spends five million dollars per year in AE designed projects. This dollar amount accomplishes 16-19 projects. While accomplishing these AE designed projects, approximately 337 contract drawings are drafted.

Research Question Nine

WHAT CAD SYSTEMS ARE CURRENTLY UTILIZED BY DOD ORGANIZATIONS?

(See Literature Review)

Research Question Ten

WHAT CAD SYSTEMS ARE CURRENTLY UTILIZED BY CIVILIAN ARCHITECTURAL-ENGINEERING FIRMS?

(See Literature Review)

VI. Conclusions and Recommendations

Introduction

This section of the thesis pulls together the many diverse research questions to answer the research objective:

GIVEN THE PRESENT LEVEL OF TECHNICAL ABILITY OF ARCHITECTS AND ENGINEERS IN A BASE CIVIL ENGINEERING TECHNICAL DESIGN SECTION, WHAT COMPUTER-AIDED DESIGN AND DRAFTING HARDWARE AND SOFTWARE WOULD BE APPROPRIATE TO INCREASE THE QUANTITY AND QUALITY OF DESIGNS?

Conclusions

The results of the project data survey sent to the Chief of the Engineering and Environmental Planning Branch at each CONUS base suggests that Civil Engineering designers are competent enough to design projects which are currently designed by civilian AE firms. From the data received in this survey, 4/5 of all AE design (4 million dollars/average CONUS base) could be completed by in-house designers, if these designers had the time. The savings to an average

CONUS Civil Engineering Squadron would be approximately 240 thousand dollars. This savings could easily pay for the Computer-Aided Design system to increase the quantity and quality of design currently conducted by AE firms, and design accomplished in-house (12 million dollars/average AFB).

Any computer-aided design system acquired for a Civil Engineering Technical Design Section should be a micro-computer with both design and drafting capabilities. This computer-aided system should have the following attributes (TABLE 6.1):

TABLE 6.1

CAD Hardware and Software Needs

1. Analysis programs
2. 3 Dimensional in nature
3. Bill of materials
4. Code compliance
5 Schematic design
6. Layer one drawing on top of another
7. Project management
8. Specifications

This computer-aided system should have the ability to store data for repetitive jobs (i.e. structural details), and have the ability to modify and save various drawings. Finally, all information should be accessible to all designers.

As far as CAD hardware is concerned, from analysis of the AFLC CAD survey, a 2:1 ratio of designers and draftsmen to computer workstation may be appropriate. The following workstation requirements were identified (TABLE 6.2):

TABLE 6.2

Number of Workstations

Base Size	Design	Drafting	Total
Small	5	3	8
Medium	6	4	10
Large	11	5	16
Average	7	4	11

Current Design Practice. Officers in a design capacity spend at least 62% of their time on design related tasks. Officers currently spend the majority of their time working with specifications and working drawings, while design analysis/calculations, schematic design, cost estimating, code checks and project management take a back seat. Current design practice appears to center around the product (specifications and working drawings), not around analysis and synthesis to determine the optimal design.

This fact of non-optimization of design is shown by current and past designers wanting to abstain from cutting and pasting, and officers wanting to look at more alternative designs. Cut and pasting is great for details, but an entire design cannot be built on putting these details together.

If a standard, technical design organization is to be employed, both designers and draftsmen must have access to the computer-aided design and drafting systems. Draftsmen need to be trained, and as-builts need to be verified and condensed for a more permanent and more easily updated format. Many civilian and DOD design organizations have a variety of purposes for employing CAD in various configurations. These organizations can serve as models for a Civil Engineering Technical Design Section's use of CAD.

Training. Without the ability to train personnel on a CAD system, problems may arise. Thus, the survey looked at how Civil Engineering designers are trained to determine the best avenue of training. The average base level designer relies on the Air Force Institute of Technology School of

Civil Engineering (AFIT), peers, senior civilians, and himself to gain knowledge to accomplish design. Although many of the current officers have training in computer languages and CAD; a training avenue to teach CAD will be needed. Supervisors are not trainers, while peers, and senior civilians may not have any CAD background. Furthermore, self-learning is not an easy way to learn how to use a CAD system. Although any CAD system bought will have either on or off-site training by the manufacturer, CAD training beyond this will most likely fall squarely on the AFIT School of Civil Engineering.

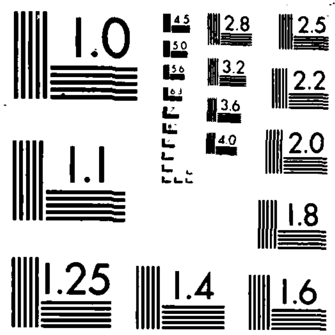
Limitations

This thesis was based on feedback from the military members of the design section. Although this author feels that the civilian co-worker should not have very different attitudes towards CAD, civilian attitudes need to be verified to determine where they stand on this issue. The electrical and mechanical engineer cannot be broken out into an in-design group, and therefore, some data may not be representative of current design practice.

This research did not look at how the Technical Design Section interacts with the rest of the Civil Engineering

AD-A175 038 COMPUTER-AIDED SYSTEM NEEDS FOR THE TECHNICAL DESIGN SECTION OF THE BASE..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. J P MITNIK SEP 86 AFIT/GEM/DEM/86S-19 2/2

UNCLASSIFIED F/G 9/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Squadron, for example, much drafting is accomplished for the Environmental and Contract Planning Section. Specifically, the influx of Computer-Aided Comprehensive Plans should have a large impact upon the shape of computer hardware which should be acquired for the Engineering and Environmental Planning Branch.

Recommendations

The list of current analysis/calculations should be used by the implementors of WIMS to acquire commercially available software for use on the Wang computer. The identified requirements of the design section should be used in sizing a CAD system for a Civil Engineering Squadron, and that requirements for hardware/software be used to decide upon the best computer-aided system for the Civil Engineering Squadron. This computer-aided system should not be only a drafting system, but also a design system to help design staffs.

Further Research

Further research should be performed to identify any special needs of civilian designers in Civil Engineering.

Likewise, further research in the hardware needs of the entire Civil Engineering Squadron should be accomplished. Other research could be accomplished to determine how a computer-aided system could be linked within a squadron to not only accomplish design and drafting, but also comprehensive planning, and all planning of projects for the shops. One could also determine procedures to update as-built drawings, and keep them current. Other research could focus on equipment to copy current as-builts. Another research topic could investigate the application of translators which transfer data from from mini- to micro-computers. Furthermore, how should a CAD system be used for Air Force Regional Civil Engineers, Army Corps of Engineers, and civilian Architectural-Engineers? Finally, one could determine the standards for AE computer use, to determine Air Force Civil Engineering's future CAD route, and how to remain compatible with AE computer systems with which we are doing business.

Appendix A: Design and Project Data Surveys

DESIGN SURVEY TO DETERMINE
COMPUTER-AIDED DESIGN AND DRAFTING
HARDWARE AND SOFTWARE NEEDS OF THE BASE
CIVIL ENGINEERING TECHNICAL DESIGN SECTION

Instructions: Answer all items by filling in the appropriate spaces on the machine scored response form (AFIT Form 11D) provided. Select only one response to each item and cleanly erase any response you change. If for any item you do not find a response that fits your situation exactly, use the one that is closest to the way you feel. Please answer each item as honestly and frankly as possible.

Section I: BACKGROUND INFORMATION

1. Have you ever worked in the Technical Design Section as a designer?

   A. Yes   B. No

2. Are you a commissioned Air Force officer?

   A. Yes   B. No

IF YOU ANSWERED NO TO EITHER QUESTION 1 OR QUESTION 2, GO NO FURTHER. PLEASE RETURN THE SURVEY IN THE ENCLOSED ENVELOPE. THANK YOU!

3. What is your current rank?

   A. Second Lieutenant
   B. First Lieutenant
   C. Captain
   D. Major
   E. Lieutenant Colonel
   F. Other

4. Years of commissioned service?

A. Less than 6 months
B. 6 months to 1 year
C. 1 to 2 years
D. 2 to 3 years
E. 3 to 4 years
F. Less than 6 years
G. Greater than 6 years

5. How long have you worked or did you work as a designer in the Technical Design Section?

A. Less than 6 months
B. 6 months to 1 year
C. 1 to 2 years
D. 2 to 3 years
E. 3 to 4 years
F. Less than 6 years
G. Greater than 6 years
H. Never worked as a designer

6. If you are not presently working as a designer, when was the last time you worked as a designer?

A. Less than 6 months
B. 6 months to 1 year
C. 1 to 2 years
D. 2 to 3 years
E. 3 to 4 years
F. Less than 6 years
G. Greater than 6 years
H. Never worked as a designer

7. Is this your first assignment as a commissioned officer?

A. Yes B. No

8. What Major Command do you work for?

A. ATC
B. AAC
C AFLC
D. AFSC
E. MAC
F. SPACECMD
G. SAC
H. TAC
I. Other (please specify)

9. What is your area of specialization?

A. Architect
B. Civil Engineer
C. Electrical Engineer
D. Industrial Engineer
E. Mechanical Engineer
F. Other (please specify)

10. What is your present level of assignment?

A. Air Staff Level
B. Major Command Level
C. Base Level
D. Other (please specify)

Section II: WORK STATION BACKGROUND Fill out this section only if you are currently working as a designer.

11. How many architects and engineers accomplish design in the Technical Design Section?

___Civilian ___Military

12. How many draftsmen accomplish drafting for the Technical Design Section?

___Civilian ___Military

Section III: TRAINING We are interested in your feelings about training in the Technical Design Section. Please use the following scale to answer items 13-19.

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
A	B	C	D	E

13. I feel I've received proper on-the-job training to accomplish my job.

14. The information/ knowledge I receive from attending AFIT courses is an important source of information to accomplish design.

15. The information/ knowledge I receive from self-learning is an important source of information to accomplish design.

16. The information/ knowledge I receive from senior civilian architects or engineers is an important source of information to accomplish design.

17. The information/ knowledge I receive from my supervisor is an important source of information to accomplish design.

18. The information/ knowledge I receive from my peers is an important source of information to accomplish design.

19. I feel capable of performing design.

Section IV: DESIGN We are interested in your feelings about accomplishing design in the Technical Design Section of a Civil Engineering Squadron. Please use the following scale to answer items 20-47.

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
A	B	C	D	E

20. My design projects are always adequately developed.

21. I look at adequate numbers of design alternatives to make the best design decisions.

22. I would like to look at more design alternatives in future design projects.

23. I feel it essential to understand what my design looks like in three dimensions.

24. I use three dimensional models in solving design problems.

25. I would like to use 3D models in my design analysis.

26. I always rely on as-built drawings, as is. They are very reliable, and do not need to be verified.

27. I always go out and check as-built drawings against existing conditions before attempting a design.

28. I always send someone out to check as-built drawings against existing conditions before attempting a design.

29. I have a difficult time cross-checking all drawings and specifications.

30. I spend a great deal of time cross-checking drawings and specifications.

31. I would like more time to cross - check drawings and specifications.

32. I generally do most of my own drafting.

STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE
A	B	C	D	E

33. I would like to do more drafting of contract drawings.

34. Most of my designs are cut and pasted from existing building design documents.

35. I would like to get away from having to cut and paste designs.

36. I always have plenty of time to accomplish design projects

37. If I had more time, I could produce a better design.

38. I spend a great deal of time managing designs completed by an Architectural-Engineering firm.

39. I spend a great deal of time managing in-house design projects.

40. I complete many calculations while accomplishing design.

41. I have a difficult time cross-referencing all drawings.

42. I can rely upon all drawings accomplished by draftsmen being error free.

43. I spend a great deal of time determining the "concept" or approach to a specific design

44. I spend a great deal of time checking codes which apply to my design.

45. I accomplish enough cost estimates to have a handle on construction costs at all times.

46. The Technical Design Section I work in manages design of projects satisfactorily.

47. I am satisfied with the technology available to accomplish design in my Technical Design Section.

Section V: EXISTING WORK RATING In this section, we are interested in what tasks you perform most. Please rank order the 7 positions (items 48 - 54) on the machine scored response form using a scale from "A" to "G", where "A" is where you spend MOST OF YOUR TIME and "F" is where you spend the LEAST AMOUNT OF YOUR TIME Use "G", NEVER ACCOMPLISH, as many times as you want. To assist you with this, the following chart indicates a number ranking and the corresponding letter response.

	MOST TIME <———				———> LEAST TIME		
Number Ranking	1	2	3	4	5	6	NEVER ACCOMPLISH
Letter Response	A	B	C	D	E	F	G

48. _____ Code Checks
49. _____ Cost Estimating
50. _____ Design Analysis/Calculations
51. _____ Project Management (AE or in-house)
52. _____ Schematic Design (Initial layout of a design)
53. _____ Specifications
54. _____ Working Drawings

55. What percentage of your total weekly work time do you spend accomplishing the tasks above?

10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
A	B	C	D	E	F	G	H	I	J

56. What types of design analysis and/or calculations do you accomplish while designing?

57. Are any of these analysis/calculations computer based?

A. Yes B. No

58. If YES to question 57, what types of computer hardware/ software do you use?

59. In what ways do you believe a computer-aided design and drafting system could improve production and quality of designs of the Technical Design Section? How would you use this system? Please use the back of the sheet if you need more room.

60. List any training or experience you have with computer - aided design and drafting systems. Please use the back of the sheet, if you need more room.

THANK YOU FOR YOUR PARTICIPATION IN THE SURVEY!

PROJECT DATA

1. Base Size 1 2 3

2. What is the total number of projects and their respective costs for the last two years for your base? DO NOT INCLUDE MILITARY CONTRUCTION PROJECTS (MCP)!

1984: ______ PROJECTS, COSTING _______ DOLLARS

1985: ______ PROJECTS, COSTING _______ DOLLARS

3. What is the total number of projects and their respective costs for the last two years that were designed by an Architectural-Engineering firm for your base? Break these projects out by the reason why they were given to an Architectural-Engineering (AE) firm. DO NOT INCLUDE MILITARY CONSTRUCTION PROJECTS (MCP)!

Reasons for having an AE firm design a project are these:

a. The Civil Engineering Technical Design Section did not have the time or manpower to complete the project.

b. The Civil Engineering Technical Design Section did not have the expertise to design the project.

c. Other reason for not designing in-house (PLEASE EXPLAIN).

1984: a. ___ PROJECTS, COSTING _______ DOLLARS.

b. ___ PROJECTS, COSTING _______ DOLLARS

c. ___ PROJECTS, COSTING _______ DOLLARS

1985: a. ___ PROJECTS, COSTING _______ DOLLARS.

b. ___ PROJECTS, COSTING _______ DOLLARS

c. ___ PROJECTS, COSTING _______ DOLLARS

4. How many architects and engineers accomplish design in the Technical Design Section?

___ Civilian ___ Military

5. How many draftsmen accomplish drafting for the Technical Design Section?

___ Civilian ___ Military

THANK YOU FOR PARTICIPATION IN THIS SURVEY!

Appendix B: Project Data Survey Mailing List/ Base Populations

Category 1 (small)

Base	Population*
Chief of Engineering and Environmental Planning 97 CES/DEE Blytheville AFB, Ark 72315	3,228
Chief of Engineering and Environmental Planning 14 CES/DEE Columbus AFB, Miss 39701	3,610
Chief of Engineering and Environmental Planning 23 CES/DEE England AFB, La 71311	3,709
Chief of Engineering and Environmental Planning 3480 CES/DEE Goodfellow AFB, Tex 76908	2,971
Chief of Engineering and Environmental Planning 305 CES/DEE Grissom AFB, Ind 46971	3,525
Chief of Engineering and Environmental Planning 47 CES/DEE Laughlin AFB, Tex 78843	3,910
Chief of Engineering and Environmental Planning 354 CES/DEE Myrtle Beach AFB, S Car 29579	3,905

Chief of Engineering
and Environmental Planning
64 CES/DEE
Reese AFB, Tex 79489

3,230

Chief of Engineering
and Environmental Planning
351 CES/DEE
Whiteman AFB, Mo 65305

3,383

*Combined military and civilian personnel assigned as by Air Force Magazine, May 1985.

Base Populations
Category 2 (medium)

Base	Population*
Chief of Engineering and Environmental Planning 443 CES/DEE Altus AFB, Okla 73523	4,536
Chief of Engineering and Environmental Planning 1776 CES/DEE Andrews AFB, Mld 20331	7,912
Chief of Engineering and Environmental Planning 9 CES/DEE Beale AFB, Cal 95903	5,595
Chief of Engineering and Environmental Planning 67 CES/DEE Bergstrom AFB, Tex 78743	6,159
Chief of Engineering and Environmental Planning 1100 CES/DEE Bolling AFB, Wash DC 20332	4,534
Chief of Engineering and Environmental Planning 27 CES/DEE Cannon AFB, N Mex 88103	4,591
Chief of Engineering and Environmental Planning 7 CES/DEE Carswell AFB, Tex 76127	6,011
Chief of Engineering and Environmental Planning 93 CES/DEE Castle AFB, Cal 95342	5,489

Chief of Engineering and Environmental Planning 3345 CES/DEE Chanute AFB, Ill 61868	7,810
Chief of Engineering and Environmental Planning 836 CES/DEE Davis Monthan AFB, Az 85707	7,237
Chief of Engineering and Environmental Planning 436 CES/DEE Dover AFB, Del 19902	6,234
Chief of Engineering and Environmental Planning 96 CES/DEE Dyess AFB, Tex 79607	6,397
Chief of Engineering and Environmental Planning 44 CES/DEE Ellsworth AFB, S Dak 57706	7,233
Chief of Engineering and Environmental Planning 92 CES/DEE Fairchild AFB, Wash 99011	4,984
Chief of Engineering and Environmental Planning 90 CES/DEE F E Warren AFB, Wyo 82001	4,049
Chief of Engineering and Environmental Planning 331 CES/DEE George AFB, Cal 92394	6,461

Chief of Engineering and Environmental Planning 321 CES/DEE Grand Forks AFB, N Dak 58205	6,032
Chief of Engineering and Environmental Planning 3245 CES/DEE Hanscom AFB, Mass 01731	5,200
Chief of Engineering and Environmental Planning 833 CES/DEE Holloman AFB, N Mex 88330	7,738
Chief of Engineering and Environmental Planning 410 CES/DEE K I Sawyer AFB, Mich 49843	4,621
Chief of Engineering and Environmental Planning 42 CES/DEE Loring AFB, Mne 04751	4,479
Chief of Engineering and Environmental Planning 832 CES/DEE Luke AFB, Az 85039	7,420
Chief of Engineering and Environmental Planning 341 CES/DEE Malmstrom AFB, Mont 59402	4,425
Chief of Engineering and Environmental Planning 22 CES/DEE March AFB, Cal 92518	5,235

Chief of Engineering and Environmental Planning 323 CES/DEE Mather AFB, Cal 95655	6,350
Chief of Engineering and Environmental Planning 3800 CES/DEE Maxwell AFB, Ala 36112	4,878
Chief of Engineering and Environmental Planning 62 CES/DEE McChord AFB, Wash 98438	7,813
Chief of Engineering and Environmental Planning 384 CES/DEE McConnell AFB, Kan 67221	5,015
Chief of Engineering and Environmental Planning 438 CES/DEE McGuire AFB, NJ 08641	6,737
Chief of Engineering and Environmental Planning 91 CES/DEE Minot AFB, N Dak 58705	6,629
Chief of Engineering and Environmental Planning 347 CES/DEE Moody AFB, Ga 31699	4,034
Chief of Engineering and Environmental Planning 6550 CES/DEE Patrick AFB, Fla 32925	5,158

Chief of Engineering and Environmental Planning 509 CES/DEE Pease AFB, NH 03801	4,105
Chief of Engineering and Environmental Planning Stop 37 1001 CES/DEE Peterson AFB, Col 80914	5,306
Chief of Engineering and Environmental Planning 380 CES/DEE Plattsburgh AFB, NY 12903	4,700
Chief of Engineering and Environmental Planning 317 CES/DEE Pope AFB, N Car 28308	4,558
Chief of Engineering and Environmental Planning 4 CES/DEE Seymour Johnson AFB, N Car 27531	6,258
Chief of Engineering and Environmental Planning 363 CES/DEE Shaw AFB, S Car 29152	7,791
Chief of Engineering and Environmental Planning 325 CES/DEE Tyndall AFB, Fla 32403	6,350
Chief of Engineering and Environmental Planning 7625 CES/DEE USAF Academy, Col 80840	4,275

Chief of Engineering and Environmental Planning 4392 CES/DEE Vandenberg AFB, Cal 93437	6,570
Chief of Engineering and Environmental Planning 82 CES/DEE Williams AFB, Az 85224	4 500
Chief of Engineering and Environmental Planning 379 CES/DEE Wurtsmith AFB, Mich 48753	4,005

*Combined military and civilian personnel assigned as by Air Force Magazine, May 1985.

Base Populations
Category 3 (large)

Base	Population*
Chief of Engineering and Environmental Planning 2 CES/DEE Barksdale AFB, La 71110	8,100
Chief of Engineering and Environmental Planning 437 CES/DEE Charleston AFB, S Car 29404	9,041
Chief of Engineering and Environmental Planning 6510 CES/DEE Edwards AFB, Cal 93523	10,152
Chief of Engineering and Environmental Planning 2849 CES/DEE Hill AFB, Utah 84056	20,700
Chief of Engineering and Environmental Planning 31 CES/DEE Homestead AFB, Fla 33039	12,690
Chief of Engineering and Environmental Planning 3380 CES/DEE Keesler AFB, Miss 39534	14,786
Chief of Engineering and Environmental Planning 1606 CES/DEE Kirtland AFB, N Mex 87117	19,360
Chief of Engineering and Environmental Planning 1 CES/DEE Langley AFB, Vir 23665	11,804

Chief of Engineering and Environmental Planning 314 CES/DEE Little Rock AFB, Ark 72099	8,300
Chief of Engineering and Environmental Planning 3415 CES/DEE Lowry AFB, Col 80230	14,394
Chief of Engineering and Environmental Planning 56 CES/DEE MacDill AFB, Fla 33608	8,792
Chief of Engineering and Environmental Planning 2852 CES/DEE McClellan AFB, Cal 95652	13,228
Chief of Engineering and Environmental Planning 554 CEOS/DEE Nellis AFB, Nev 89191	11,827
Chief of Engineering and Environmental Planning 63 CES/DEE Norton AFB, Cal 92409	8,304
Chief of Engineering and Environmental Planning 55 CES/DEE Offutt AFB, Neb 68113	15,276
Chief of Engineering and Environmental Planning 2853 CES/DEE Robins AFB, Ga 31098	20,048

Chief of Engineering and Environmental Planning 375 CES/DEE Scott AFB, Ill 62225	10,912
Chief of Engineering and Environmental Planning 3750 CES/DEE Sheppard AFB, Tex 76311	9,431
Chief of Engineering and Environmental Planning 2854 CES/DEE Tinker AFB, Okla 73145	25,181
Chief of Engineering and Environmental Planning 60 CES/DEE Travis AFB, Cal 94535	15,707
Chief of Engineering and Environmental Planning 2750 CES/DEE Wright-Patterson AFB, Ohio 45433	32,000

*Combined military and civilian personnel assigned as by Air Force Magazine, May 1985.

Appendix C: Data Files

This appendix contains the data files used to perform the various analyses contained in this thesis. Blank spaces in data file A indicate that the respondent did not answer the question or that a fill-in-the-blank question was asked.

The following format applies to data acquired during the design survey:

Format Data File A: Design Survey

Column	Survey Question
1- 10	Demographic Questions
11- 12	Fill-in Questions
13- 19	Training Questions
20- 47	Design Questions
48- 54	Existing Work Rating Questions
55	Percentage of Time Spent on Design
56	Fill-in Question
57	Computer Based Design
58- 60	Fill-in Questions

The following format applies to data acquired in the Project Data survey:

Format Data File B: Project Data Survey

Row	Survey Questions
1	Base Size/ 1984 Total Design Project,Dollar/ 1985 Total Design Project,Dollar
2	1984 AE Projects:A Project,Dollar/ B Project,Dollar/ C Project,Dollar
3	1985 AE Projects:A Project,Dollar/ B Project,Dollar/ C Project Dollar
4	Designer:Civilian,Military/ Draftsmen:Civilian,Military

A. Technical Design Section did not have the time/manpower
B. Technical Design Section did not have the expertise.
C. Other reason for not designing in-house.

The following format applies to data derived from the 1983 AFLC CAD survey:

Format Data File C: 1983 AFLC CAD Survey

Row	Column	Survey Questions
1-8	1	Base 1(Hill),2(McClellan),3(Robins), 4(Tinker),5(Wright-Patterson).
	3- 4	Date(year)
	5	1(in-house),2(AE)
	7- 9	Architectural Drawings(in-house)
	11-13	Architectural Drawings(AE)
	15-17	Civil Drawings(in-house)
	19-21	Civil Drawings(AE)
	23-25	Mechanical Drawings(in-house)
	27-29	Mechanical Drawings(AE)
	31-33	Electrical Drawings(in-house)
	35-37	Electrical Drawings(AE)
	39-41	Other Drawings(in-house)
	43-45	Other Drawings(AE)
9	12-13	Number of Civilian Designers
	20-21	Number of Military Designers
	28-29	Number of Civilian Draftsmen
	36-37	Number of Military Draftsmen
10	6- 9	Yearly Architectural Design Hours
	13-17	Yearly Civil Design Hours
	21-25	Yearly Electrical Design Hours
	29-33	Yearly Mechanical Design Hours
	37-41	Yearly Other Design Hours
11	6- 9	Yearly Architectural Drafting Hours
	13-17	Yearly Civil Drafting Hours
	21-25	Yearly Electrical Drafting Hours
	29-33	Yearly Mechanical Drafting Hours
	37-41	Yearly Other Drafting Hours
12	6- 9	Yearly Architectural Other Hours
	13-17	Yearly Civil Other Hours
	21-25	Yearly Electrical Other Hours
	29-33	Yearly Mechanical Other Hours
	37-41	Yearly Other Other Hours
13	6- 9	Yearly Architectural Admin. Hours
	13-17	Yearly Civil Admin. Hours
	21-25	Yearly Electrical Admin. Hours
	29-33	Yearly Mechanical Admin. Hours
	37-41	Yearly Other Admin. Hours

Data File A: Design Survey

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Data File B: Project Data Survey

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Data File C: 1983 AFLC CAD Survey

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    17472   18720   11232   11232   15600
```

Appendix D: Analysis/Calculations by Specialties

Architectural Analysis/Calculations

1. Structural Analysis (foundation,beam,column) 37
2. Cost Estimating 24
3. Architectural layout (space,circulation,flow,functional, bubble diagrams,user needs) 20
4. Quantity take-offs 13
5. Square footages 12
6. Space allocation (utilization,requirements) 10
7. Cost analysis (alternatives) 10
8. Energy conservation (heat retention) 7
9. Fire code (lifesafety,others) 6
10. Sketching (isometrics,axionometric,perspective) 6
11. Lighting loads (electrical levels,energy) 5
12. Material selection 5
13. Zonal cavity 4
14. Vapor barrier 4
15. Solar feasibility (penetration,passive) 3
16. Acoustic (noise) 2
17. Project management 2
18. AE fees 1
19. Economic Analysis 1
20. Specifications 1
21. Wind loads 1
22. Mechanical loads 1
23. Traffic (pedestrian flow) 1
24. Site analysis 1
25. Parking requirements 1

Civil Analysis/Calculations

1. Structural analysis (concrete,steel,wood) 30
2. Concrete design (foundation,walls,footing) 27
3. Simple structural beams and columns 23
4. Pavement capacity (analysis/design,flexible/rigid, sidewalks) 18
5. Steel design (connections) 9
6. Cost estimating 9
7. Pipe flow (open channels,fluid,pressure,pipe loss, velocity,headloss) 8
8. Rainfall/stormwater run-off (drainage) 8
9. Floor and roof load Analysis (loadbearing) 7
10. Wind load analysis 7
11. Soil capacity analysis (shear/compression) 6
12. Simple structural calculations (rafter,truss) 5
13. Wood design 4
14. Snow loads 4
15. Quantity take-off 4
16. Concrete/ steel codechecks 3
17. Sewer design 2
18. Fire code 1
19. Mechanical 1
20. Electrical 1
21. Grading/ earthwork calculations 1
22. Earth pressure on underground structures 1
23 Traffic load and frequency 1
24. Lifecycle 1
25. Energy 1
26. Feasibility 1
27. Engineering Economics 1

Electrical Analysis/Calculations

1. Load calculations (circuit,maximum KVA,power) 27
2. Lighting (levels,loads,alignment) 26
3. Wire/conductor sizing 16
4. Short circuit analysis/fault current/ switch load analysis 11
5 Motor/generator sizing 11
6. Voltage drops 9
7. National Electric Code checks 5
8. Power consumption (utility charge 5
9. Transformer balancing 4
10. Equipment sizing 4
11. Panel sizing 4
12. Cost Estimating 3
13. Transformer sizing 3
14. Current balancing 2
15. Fire alarm 2
16. Circuit breaker/ fuse sizing 2
17. Panel balancing 2
18. Capacitor sizing 1

Mechanical Analysis/Calculations

1. Heating, ventilating, and air conditioning (HVAC) load estimating 44
2. HVAC duct sizing and design (cfm, static pressure,velocity,friction loss) 26
3. Pipe sizing (plumbing,head,flowrate,pressure drop) 24
4. HVAC equipment selection 14
5. Cost estimating (analysis) 8
6. Energy conservation (u factor,infiltration.heat loss heat transfer) 8
7. Pump sizing 6
8 Energy consumption 6
9. Control system design 5
10. Fan sizing 3*
11. Coil selection (hot water,cold water) 3
12. Sprinkler system analysis 3
13. Life cycle cost analysis 2
14. Boiler sizing 2
15. Psycometric 2
16. Steam/hot water converter sizing 2
17. Ventilation 2
18. Humidification/dehumidification 2
19. Heat exchanger 1
20. Water vapor 1
21. Space utilization 1
22 Floor loads 1
23. Valve sizing 1
24. Water demand 1
25. Refrigerant line sizing 1
26. Thrust blocks for sewer lines 1
27. Domestic hot water sizing 1
28. Chiller sizing 1
29. Heat pump 1
30. Utilities 1
31. Fire suppression systems 1
32. Chemical compatibility 1

Appendix E: Hardware and Software in Use at Base Technical Design Sections

We have a Textronix computer and CalComp plotter which produce drawings of previous inputs. In our application, a CAD is unrealistic because most of our projects are minor renovations to electrical configurations based on computer equipment relocations and installations. Minor halon reconfiguration may be required if area dimensions change. Used by draftsmen, not engineers.

We have a Zenith Z-100, but we (the engineers in design) are not allowed to use it. It currently is being used by the programmers in the DEEV branch.

Drafting section at our base uses Macintosh PC for graphics. Very helpful.

We presently have a 2-D CAD monotone screen (circa 1980). This system is slow compared to todays' 3-D CAD, but we have found many uses for it (ie. built-up roof plans, pavement plans, symbols of aircraft, graphs, charts, etc.).

Our section currently has two Zenith 150's and are awaiting the design software to reduce the tedius number crunching.

VersaCAD CADCAM and self-generated programs.

My own software and hardware: ALLWET (Corps of Engineers program for waterlines/ hardy cross model); STRESS (structural analysis program); IBM PC XT.

Wang VS 100 computer with in-house developed software.

CALCSTATIS from IBM.

I write my own programs for ductwork and piping design/ analysis on an Apple II+.

Apple II.

Apple III.

Z-100 microcomputer.

Zenith 100 with AutoCAD software and a Hewlett Packard printer.

Lotus 1-2-3

HP 41 CV (personally owned), and a Zenith 100 which requires personal programming, with few commercial programs being compatible.

Wang VS 100 with control, word processing, data entry, report and 2020 spreadsheet. Wang PC with Multiplan spreadsheet, word processing. Zenith 171 with Supercalc 3 spreadsheet.

Zenith 100 with Z-Basic.

Lighting level and Panelboard layouts.

Zenith Z-100 to figure out "U" factor and heat load. Both programs are commercially available. Life cycle costs are also calculated.

Self written BASIC program on the Zenith 100 computer.

Carrier E 20-2 heatload analysis.

IBM PC with AutoCAD. IBM PC AT with in-house developed software. IBM 4341 with in-house developed software. AMDAHL 8081 with in-house developed software.

IBM PC with Primavera software and a CalComp series 25 plotter

Z-100 with ASHRAE load calculation software by Elite.

Z-100 with BASIC programming

Hand-held programmable calculator.

I will soon be receiving some 'home brewed' programs for lighting design and voltage drop from a former co-worker for the Zenith 100.

TRACE program. I have a Fortran code that I have written, but I don't have a Fortran compiler.

Zenith 100.

Televideo XL portable computer (IBM compatible) with 10 Megabyte Hard Disk with STAAD-III FEA program.

Z-100 PC with Lotus 1-2-3.

USAF Wang with PDC solar and Air Force construction pricing guide.

Z-DOS and MS-DOS operating systems with in-house developed programs.

Use FORTRAN and public domain software.

PAVER for personal computer.

I've tried asking for funds to go to a CAD orientation course, but the usual reply of non sufficient funds detered me from going. I worked on the Z-100 using PeachText. Database and PeachCalc. Also, I've noticed most of the Z-100's on base are under-utilized. I have applied for an on base training of Lotus 1-2-3, and database 2 so I can use it before going overseas.

I use existing computer programs learned by self help.

No formal training, but I program to aid with calculations on the Zenith 100 in design.

I course direct and teach the architectural design course using CADD at the US Air Force Academy. We use AutoCAD and Zenith Z-248 microcomputers with a 20 megabyte hard disk.

Appendix F: How Officers in the Design Section would Use a Computer-Aided Design System

1. Alternative/detailed design analysis 54*
2. Calculations 53
3. Decrease drafting time 52
4. Update as-built (better) 47
5. Modify drawings quicker 43
6. Cut and paste repetitive jobs (detail) 37
7. Reduce design time (quality/direct usage) 31
8. 3D 30
9. Professional product (clean/standardized/QC) 30
10. Cost estimate (local info) 26
11. Specifications (standardized) 26
12. Reduce errors 21
13. Concept/schematic 16
14. Better design 15
15. CAD is not warranted for us 15
16. Find conflicts in design 14
17. Share info between designers 14
18. Intelligent/accessible (optimization) database 12
19. Reduce manning in drafting 10
20. Material options/products/references 9
21. Codes 6
22. Project management 6
23. Generic designs (standardized) 6
24. Cross-reference drawings and specs 3

*Number of Responses.

Selected Responses of how Designers would use a CAD System

Please don't confuse drafting production with computer-aided design. They are apples and oranges and require two entirely different hardware make-ups. A CAD system would greatly improve the potential for accuracy of as-built drawings. This factor alone would greatly reduce the amount of headaches associated with designing additions and other retro fit projects. The drawings could also be projected in 3-D which would cut down on the need of additional site visits. The system could be used to test the functional response of the design. If a door is proposed that won't be able to swing open because of obstruction, the CAD system could alert the designer of such problems.

I believe they would eliminate 90% of drafting workload. Drafting could be accomplished by engineers. This would eliminate duplication of work and be more accurate. Details could be maintained in a file and used as needed. Programs could be generated to select lighting and protection devices ensuring adequate and coordinated facilities. Companies that manufacture products could supply programs that would cross index their products with other similar ones. This would give better selection and more extensive product information.

A CAD would be a time-saver in developing and designing projects. In addition, it would help centralize a designers work in front of him, thus allowing more flexibility in relating specs with drawings, codes, peer input; and seeing results right away without delay for drafting or cut and pasting. I'd use a 3-D CAD amongst all engineers so that each discipline (civil, arch, elect, mech) can work on the same plan and thus be aware of changes or problems immediately.

Also, due to the inexperience of draftsmen entering this field, it becomes even more of a timesaver.

Hydraulic design of fire protection system can be done in CAD for AF facilities.

In the field of HVAC. Load estimating takes most of my time. A DOE.2.1 software is available in the market (using IBM PC XT or AT) which can save the government and the DOD a big amount of construction/ design dollars.

In the controls design, the new ETL and AFR 88 15 criteria of single zone, and multizone prototype schematics developed by AFIT are very Greek to the AE that I have worked with. It seems sometines, and most of the time that we are using some-things with the AE is not really very familiar with.

Suggest we initiate educating the civilian AE of our new 88-15/ETL controls system design standards.

Stress sending our technicians to Sheppards control trouble shooting course.

CAD would help make up time shortages in at least two areas
1) There is a lack of understanding amongst many AF designers in the "how to" of construction. Too much time is spent looking at floor plans and not enough on sections and details. The CAD will give us 3-dimensional visualization for investigation without taking the time that building models takes
2) The CAD would reduce the time it takes to update a project in its final stages, leaving more time for initial investigation and development.

To begin let me explain the way things are now. An engineer must draw his design to the point that it can be traced by the draftsmen. They are poorly trained and cannot understand design concepts like exactly what needs to be shown in a building section. They have a hard time understanding or visualizing drawings and as a result are happy to sit and trace all day, everyday.

A properly trained engineer could "design" on the computer so that once he's spent as much time on the computer, as he usually does getting a design ready to be traced, he would have a product which could be drawn by a plotter and could be signed and sent to contracting.

One of the most difficult times I have is analyzing existing structures with point and other loads to see if enough extra capacity exists to properly support additional equipment and/or change room use.

Canned programs can run out design specifications in a short while and would be more accurate than cut and paste of a similar project. A major problem at X AFB is lack of Engineering expertise. When I graduated from college and came to X AFB, I was the most experienced Civil Engineer. If I want to check calculations or talk over strategy I have to talk to myself. The Air Force has a very poor Engineering program which they could improve by encouraging engineers to become professional engineers (PE) and by hiring PE's.

All as-builts should be computer filed and updated with CAD/CAM system. Design software in all areas of expertise should be purchased. Every engineer should have a smart terminal and have recurring training at AFIT to remain current. Similarly, project management and cost estimating software should be used. This idea is resisted through the influence of entrenched supervisors who studied with slide rules and empirical data. Modems should be included for inter-base technical correspondence and reporting with majcom.

CADD works efficiently and cost effectively only with highly repetitive work such as electrical engineering sheets and basic details, symbols. 3-D is primarily a "toy" with not much real-time productivity acheived (nice to have).

Each individual base probably doesn't use CADD "enough" to pay for its own system. However sharing the database might work. Share from AFRCE mainframe to base workstations via telephone lines, and sharing database.

A potential system could be the one I had knowledge of during EWI (from training report)

I also continued observing the CADD testing in the <u>MIS</u> division. DMJM's philosophy was to test the vendor's equipment with their own management/operational procedures to determine the best product. The system that best met their needs was PRIME's Medusa System.

A brief summary of PRIME's features that come with the standard package includes:

(1) 32 Bit Architecture
(2) Local and remote networking
(3) Multi-functional
(4) Various languages compatible (i.e., Fortran, Cobol, Basic, Pascal, etc.)
(5) Electronic mail
(6) Word processing
(7) 2-D graphics
(8) User friendly menu
(9) Third party software integration
(10) Business graphics
(11) Office's worldwide for customer support
(12) Large data base

Highlighting some of these features:

A 32-bit microprocessor enables quick compilation of the data input. Most CAD systems still have 16-bit processors. Since users buy CAD for time-saving, money-saving abilities, it's extremely beneficial to have that two fold quickness. Immediate saving would be noted if the data was sent over communication lines to a remote site (less time), less network phone bill

This workstation has stand-alone capabilities with a large data base. Many users, each with their own station, locally or across country, could have access to the mainframe at the same time or work independently without the mainframe.

The workstation is comfortable and the equipment is set up for operational concerns. Eyestrain and human fatigue should be minimal with this system. The menu itself is user-friendly and training should be accomplished quickly.

Finally, PRIME has made a commitment, and is established firmly to support the CADD system on a worldwide basis. Many systems are bought by customers and then left to their own devices.

I suppose I would put more emphasis on computer-aided drafting systems than anything else. The unreliability of our "as-built" drawings is a major problem. This is not to say that our draftsmen are committing errors. Drawings which may have been created accurately become unreliable if there is no formal mechanism for updating them as the system changes. On some bases, updating drawings is not part of the "loop" for job orders/ work orders. It is felt that this task is beyond the capabilities of the existing drafting workforce. In many cases, this is indeed true. Detail Drawing of modifications are simply filed with the original system drawings, but not incorporated into the originals to create a total, up-to-date as-built. I hope that a computer aided drafting system would give us the ability to get and keep our house in order.

As for computer aided design, many of our electrical designs involve step-by-step procedures with numerous decision branches and many calculations. These design procedures are very adaptable to "number crunching" computer programs. I would use these types of programs extensively. They would be great time-savers, creating more time for pure thought processes, brainstorming, evaluation of more alternatives, etc. They would promote more thorough evaluations of more alternatives, resulting in greater safety, more economy, better design documentation, and a better overall system design.

(System) would provide opportunity to explore/consider design alternatives to make better design decisions. CAD could provide hard copy products of design options in a short period of time. These products could be used to brief supervisors and senior base officers on new ideas for enhancing overall base appearance and efficiency. Accuracy of drafting would dramatically increase. Modifications to designs in final drafting stages would be thorough. All cross referencing would be consistent. Probably most importantly, as-builts would be able to be placed on computer record and updates to as-builts would be 100% accurate and timely, thus enhancing their reliability in design/conceptual stages.

First of all, computer-aided design and drafting system produces fast and accurate products (drawings). The designs and drawings are consistent. Revisions of drawings could be done quickly and easily. In my office, there are more engineers and architects than drafting personnel. With increasing workloads and personnel turn-over, the drafting section on many occasions can not keep up. A computer-aided design and drafting system, in my opinion, certainly will alleviate this problem. Drafting personnel could produce drawings faster and engineers and architects could also help out by drafting and designing with the computer.

Come on, lets get with it. Private industry have been using computers for designs and drafting, for years. The Air Force had better use modern day technology, or else we'll be left behind in the dark ages.

We spend billions of dollars on weapons systems, but we couldn't even spend five to seven thousand dollars on a CAD system. All I could say is that pilot(s) might fly an expensive F-15, F-16, F-111 or whatever. But he will have to come back to live in a lousy MFH unit, or to work in an out-dated office building.

X CES has a CAD system, but only draftsmen use it. Engineers still sketch by hand. Also, most engineers in X CES do not use (by choice) the limited computer resources available to them. Giving more access by placing micros's on each engineer's desk and then making the people learn how to use them would help temendously.

I feel that CAD is the way of the future. Many AE firms are already using it and we (Air Force) should stay current with today's technology. I think production and quality would be improved, SIGNIFICANTLY! I would be very interested, as a designer, of learning CAD systems to that it could be applied to the Tchnical Design Section. I think this could be done through a 4 to 6 week course offered through the School of Civil Engineering, AFIT.

I have had NO training in computer-aided design or drafting I have read many articles about it, many of these articles pertaining to what the Army COE and also the Navy (NAVFAC) are doing in this area. It shows great potential! I think the Air Force should implement this program as soon as possible.

Technical Design Sections are fairly standard, thus it would provide an easily accessible catalog of sections to choose from and modify for each project. This would save time researching architectural standards books and other construction drawings. In addition, it would save time and materials in reproducing these drawings accurately.

Develop a master data base for record drawings, which would keep only the most current revisions and as-builts. Start with just floor plans and roof plans; that alone would be a great help, and may be enough in itself to sustain a small office. Engineers needing mechanical drawings could overlay on the plans, and be assured of currency and accuracy. A larger office would need, and be equipped to develop, a complete set of record drawings on disk for each facility. Also, overlays would be greatly simplified-there are always request to put, say, the water mains map over the electrical.

The engineer would be able to "draw" concepts directly into the computer rather than doing sketches on scraps of paper and relying on the draftsman to interpret the sketch. Also, the design would be able to change the design easily. The entire design could be done on the computer prior to being put down on paper eliminating much redrafting that tends to be done.

We could speed the design process. Better designs more efficiency and less errors. More visualization of total designs rather than just parts. Easier update of as-builts. Update as-builts so everything is exact and less time spent on change orders because of improper information on existing conditions. Besides this is what the world is coming to. The computer age is here and it's time the AF caught up. LET'S GO TO CAD SYSTEMS NOW. Everyone will benefit, especially the government and most importantly the budget!

A CADCAM type program would cut the amount of drafting, project layouts, and overall project time in half. Most of the design/project time is spent on reorganizing material (drawings, and specifications) from previous projects. Thus previous work could be readily available for this reorganization if stored properly in a CAD system program.

Many times design projects are held up due to lack of drafting support. In addition, time is usually spent proofing the "finished" drawings. CAD would be a step in the right direction in reducing back-ups due to drafting and checking drawings.

Word processing, cut and paste could easily be improved by having easy access to a computer with word processing capabilities. (Cut and paste is a valid/useful procedure, why re-invent the wheel?)

Simply provide us with more Zenith 100's (or equal, ha ha). We only have one available and its not even in our section. We are pretty bright people, if you provide the machines we will figure good ways to use them. A library system of programs that people come up with would be very helpful.

The engineer would not have to convey his ideas to drafting; therefore, his idea would not be lost. As an engineer I think we would get a better project/product with the engineer using CAD. You would also cut lag time in waiting for someone else to draft it.

As an ex-site developer, this would allow more time to verify as-builts for the engineer and the engineer's could review as-builts easier.

Improve drafting time-I wouldn't need to translate my ideas to a draftsman, I would just do it myself.

See different perspectives-drawings can be rotated with CAD, thus giving you a better view of the subject.

Bill-of-materials would be automatically printed, so better cost estimating.

Data base for costs would provide excellent reference.

Modifications to a design could be quicker and cheaper (not necessary to print hard copy before making modification to project under design).

More time could be spent on producing a more economical design so that change orders are not necessary. More time would be saved by CAD and specifications available to the engineer on a word processor.

Have more time to make a more detailed initial site investigation, solving a lot of problems that usually will come up at construction.

A CAD system will automate our efforts, reduce file space and improve the overall quality of our as-builts. Currently our as-builts are so unreliable that it is starting to greatly affect our design time. CAD again will automate this problem and give everyone who requires design/drawing changes the ability to make those changes on the spot and not wait until drafting has the time!

With a 3D view, various systems (ie. electrical, mechanical, structural) can all be aligned, revised as necessary to accomodate the others. Changing designs would be quick and a visible product (crt) could be viewed before the hardcopy is produced. If the Air Force is going to keep in line with current engineering proctices computer aided design is necessary to accomplish this We currently operate 5 years behind industry for similar types of work.

Would free engineers to concentrate on learning new concepts and coming up with new ideas, instead of getting bogged down in number crunching.

Would decrease turn around time in drafting.

Would cut down on "swagging" designs.

Increase production of working drawings.

Standardize some designs for common elements (eg. handicapped bathroom stalls, seismic provisions for control/expansion joints, etc.) and avoid "re-inventing" the wheel for each design.

Allow designers to spend more time in analysis and also refining specifications.

Results will be quality design with more alternatives considered and more stable/exacting specifications.

End result is satisfied client and fewer contract modifications.

System could contain a data base that includes a selection of products and materials in response to a situation input by the user. User then makes a selection based on maintenance and reliability factors (or other appropriate criteria).

Most designs involve some basic calculations. Most steps are repetitious; therefore, leading to computer programs. Also, single line drafting is very ineffective in most instances and CAD systems are very useful here. CAD systems are great for common details and tables for drawings.

Allows more expedient and uniform accomplishment of iterative processes and production, ie., details, use of symbols. Provides a standard format and appearance for contract documents. Allows for improved storage and retrieval of as-builts. Allows for ease of corrections, expecially as-builts. Lends itself to presentation, especially 3D graphics. The transfer of information from schematic design to design development to contract documents is reduced; this allows more time to manage (that's the bottom line).

The greatest need is a computer based drafting service. All of our buildings have been repaired and altered so many times that the drawings are very out of date. The advent of self-help creates a situation where floor plans and office usage are in a constant state of flux. The current as-built drawings are unorganized and in very bad shape. The quality of drafting is poor due to our whole military section being Airmen with less than 1 year experience. A computer based planning system that cross referenced all affected functions would be helpful. Often time a project is started and the enormous research effort is required in order to assure other projects are not interfering takes 50% of your time.

A computer-aided design system would aid me in laying out different designs. If I could draw-up several different ideas on a computer, I could possibly present better solutions to design problems. With draftsmen, I spend several hours waiting for my drawings. I can't afford to waste additional time working on different design concepts. A CADD system would allow me the freedom to use different design alternatives. It could possibly allow me to get my design finished sooner since I would not have to wait for draftsmen to draw-up the ideas.

Productivity could be improved by making on-the-spot corrections without having to wait days or weeks for a draftsman to get to it. A lot of renovation is done and copies of existing floor plans and "checked" as-builts could be used. Quality would depend on the engineer, but the engineer would have more time to spend researching his work, if CAD systems can put more information at the designers fingertips and cut down on drafting time.

I feel we can eliminate/reduce 50% of our contract modifications (change orders) and utility cuts that are the result of not knowing what and where base utilities are on a project.

Building modifications can be designed faster and more accurately since we could use the original building layout as the basis of the design.

After learning to use the system, the engineers could save time. CAD for facilities engineers are great if: senior engineers take time to learn to use them, accurate "as-builts" are loaded into the system first, engineers and draftsmen use the same symbols and abbreviations on a consistent basis.

In my ten years as an Engineering officer, I have spent almost an equal amount of time in both design and construction. Many of the change orders encountered during construction are a direct result of errors in the construction plans (basic error in dimensions and sizing, errors in lack of adequate space for HVAC equipment and ductwork, electrical equipment and even structural members). This could be sustantially reduced by a CAD system which could automatically check spatial relationships and coordinate locations of structural, mechanical and electrical systems.

Standardized details would simplify discrepancies between offices, as well as save dollars and time for production. Drafting quality would improve dramatically and resolve many of the proof reading errors commonly found on drawings drafted by inexperienced personnel.

With shortage of time, and lack of model development, a computer modeling system would enable designers to visualize 3D structure and massing relative to other facilities and vernacular.

I've used the MacIntosh system, it reduced design time in every circumstance. Also seen a CAD/CAM system. Fantastic. We would be quantum leaps ahead of where we are now. With that type of system, we could tie together all the engineers, draftsmen, cost estimating, etc. I am highly in favor of it!

Productivity and quality could be improved by permitting more alternate designs to be tested/reviewed. Time doesn't permit the development of alternatives or checking of design calculations. The design review process is usually cursory if done at all.

As an IG inspector now, I have found those bases with good review processes have lower "modification rates due to design errors". Most design sections have too few "experienced" engineers. The combination of filling the design section with young, inexperienced military and the large number of projects assigned to each engineer is proving fatal. Computers could greatly speed up calculations for experienced engineers and permit a better review of young engineer's work.

Since so much of AF work is spent on existing structures. CAD is extremely difficult since the initial database must be set up. CAD for calculations (ie. structural, mechanical, electrical) would be extremely helpful and time saving. Also. project management PC tools would also be extremely beneficial.

Once an "existing" database was set up through CAD for design, drafting would also be an efficient timesaving tool. The point to consider is the downtime to account for an engineers learning curve on the PC.

Initially, the best use for CADD would be in the record drawings section. They are charged with maintaining and updating all drawings. If these drawings were CADD based it would allow engineers to cross reference drawings from separate projects to avoid replacing items that were recently replaced, designing a project based on drawings that are not up to-date and allow each discipline to overlay their drawings on a given project in an attempt to eliminate inconsistencies. In the design section, CADD for drafting may be more of a luxury, but design programs are a necessity.

Allow designer to see his design in a shorter amount of time, instead of waiting for drafting. Corrections can also be done ASAP. If a printer/plotter is available. a hard copy can be seen quicker than waiting for printing backlog in drafting. Better filing system could be used. easy accss of all designs to all engineers. All engineers are not familiar with the way drawings and specs are currently filed. Almost always require a draftsman to look up drawings.

I would be able to update and/or change drawings without having to use the drafting section.

Initially there would be NO advantage (learning curve and turn-over).

Greatest advantage is the re-use of repetitive details (design), real-time calculations and cost estimates.

Make updating as-builts something the facility managers could do, as well as design section.

It would improve production and quality of designs greatly; however, keep in mind that draftsmen and engineers will need a minimun of 6 months to become literate on any CADD system and the nature of the military.what with PCS's. etc...may preclude using CADD systems Air Force wide.

Probably won't use: no time for training, do mostly management, very little design time in my future.

If all facilities were on computer, they could be easily updated and more reliance could be placed in as-built information. Confidence in this information would reduce cross-referencing time and would accelerate design time. My biggest headache is determining what is existing.

Could do my own drafting in an efficient manner. On the average. I think I'd get better support from a CAD system than from a draftsman/site developer.

I believe that design work could be accomplished much faster and easier with computer based specs, tech data and the possibility of storage through a CADD system. Our drafting system is a joke. Our engineers use the most outdated methods to design and estimate.

CAD is good for new construction and floor layouts. A lot of our work is maintenance and repair and individual details must be drawn. CAD would be very effective for new designs, elevations, etc. CAD is the wave of the future and is needed to keep AF CE in tune and competitive with private sector.

Neat, error free drawings would be great! I would like to try it out at AFIT and see if it is worthwhile to get here.

Cut manning requirements in the drafting section.
Save time on repetitious drawings.
Lessen dependency on AE firms.
Give engineers a new qualification.
Standardize base/AF/military design.

I think it would cut down drafting time greatly; therefore, more work can be completed faster. This is a must because of the large amount of back logged projects.

I feel that it would be a definite aid for developing the HVAC system. It would give us the same advantage that most AE firms have. We should be able to do more projects rather than contracting to AE's

We must keep up with technology. CAD is the way of the future It would allow an engineer without a drafting background to produce his drawings.

My experince with computer aided design work is with AE design work. Product is only as good and as reliable as the design engineer.

Especially in the military and on a base, computers should be used extensively in design and could save so much time and effort, the problem is training (or teaching old dogs' new tricks) management to see it this way. Specifications and details could be stored easily as well as many other management items, etc.

Ease of calculations, for historical and future use, quick turnaround of reviews, save time and money (can design more projects), WAY TO GO!

Air Force engineers should be kept current with the latest computer technology.

A CADD system is a highly effective and efficient means of accomplishing a vast spectrum of design requirements if used properly. However, many of our engineers are of the "OLD SCHOOL" philosophy (ie. cut and paste people) and it may take a while to convince them of the positive aspects of CADD systems. I don't know if you can say that adopting a CADD system will make "draftsmen" obsolete, for you need both to work together and that's how I would use this type of system.

Tremendous benefit!

CAD is greatly needed! The base is overloaded with design after being on a closure list for 3 years. This would save time and overtime pay and hours for engineers and draftsmen.

Excellent tool! Would love to learn! It's essential to deep abreast with industry.

In non-engineering design sections, (ie planning), this system would allow more accurate drawing preparation and layout. Shops would have a more accurate set of drawings and could interface better with each other (ie electrical, steam, structural).

The CADD would be a definite asset to our office. Proper training of of individuals to insure proper utilization would be a must. This system could be loaded to assist real property, technical design and drafting in researching and completing design.

Would be most helpful for the production and maintenance of drawings. I see little benefit for the designer unless he is trained to take advantage of three dimensional representations.

CADD has the potential to enhance the quality of design work. However, I feel the objective and purpose of CADD needs to be clearly defined or the productivity of the Technical Design Section could decrease.

Appendix G: Selected Responses of Previous Computer Training

I have worked with and/or written several number crunching type interactive computer aided design programs. These programs involve short circuit studies, lighting design, and branch circuit design.

Two courses in college dealing with CAD

On computer-aided design, I have worked with BLAST, DOE-2, E20-2, TRANSYS, F-Chart. CALPAS 3, and other thermal energy programs regularly since 1980 I have used STRUDL for structural steel analysis, and numerous spreadsheet programs for balance sheet calculations. I have written/co-authored 3 software programs for energy analysis. I have also performed lighting design and analysis by computer aided design and performed statistical analysis with SAS, MINITAB, BMDP, and SPSS. Micro, Mini, and Mainframe computers were used for this analysis.

I have a lot of experience in computer modeling and graphics using mainframe computers.

Basic and Fortran.

All of my civil engineering courses my last 2 years in college used computers to solve design problems. Not all of these would be used enough in facilities engineering to be useful, but I think it would be prudent to accomplish the following using computers: truss analysis, column and beam design, pipe network analysis and cost estimating.

I have used several commercially available programs to aid in calculations.

Personal research on CAD systems. I would like to have my own IBM PC compatible system for business and analysis at work. Demonstrations and experimenting and observing AE firm's CAD systems.

4 computer classes and 2 CAD/CAM classes in college.

A few orientation/ sales type seminars.

CAD demonstration by vendor.

I have seen demonstrations of most major CADD vendors (IBM, Intergraph, Computervision, Synercom, AutoDesk, etc). I have briefly used Intergraph and AutoCAD. I've also seen demos of scanning and digitizing using WANG PC, and Datacopy scanner on IBM PC.

I've used design programs extensively in college on Digital VAX, Texas Instruments, and Apple computers. I have no experience with drafting systems.

I have taken a CAD seminar course from Iowa State University in which we worked on a CAD system.

I worked for 13 months with IBM/RTP in Raleigh, NC in the Facilities Engineering Department. All design work was done on IBM CADAM. My senior design project in mechanical engineering at North Carolina State University was completely designed and drawn on CAD.

Education at many architectural schools requires participation in CAD classes. I worked with CAD and solid modeling systems capable of providing basic engineering analysis.

college course work

I have used AutoCAD, STRESS, and ALLWET which are IBM XT based programs.

Literature and observation of demonstrations only.

No CAD, but I am knowledgable of computer languages and logic.

I worked my summer internships at the Veteran's Administration Central Office in Washington, DC.

I have seen some CAD demonstrations - ON MY OWN TIME!

I have seen some demonstrations of Hewlett Packard CAD packages.

Introductory orientation of CAD at an American Society of Engineering Management meeting

Trade show presentations of CAD packages.

During my masters program, at the University of Texas, I used the universities design programs. I have also visited the Texas Highway Dept, which has a complete CADD system.

3 week short course at California Polytechnical Institute

I took a computer aided design and graphics course at the University of Connecticut for my Bachelors Degree. I worked with fluid Dynamics programs for my masters degree.

BASIC language course, and familiarization with CAD on a TERAK system.

Extensive college exposure.

SPICE/IGSPICE at the University of South Florida in Tampa.

CAD training during my studies for my BS in Civil Engineering

The only training I had was FORTRAN and a little programming in other college courses for design.

Seminars and computer hobby.

I used CAD a little while I was in Education with Industry Program.

1 graduate level course on CAD.

Clemson University (80-84) and Lifecycle engineering (84).

I have observed several demonstrations and used small computers to accomplish some energy calculations and design analysis in school.

While I was a senior in college, I took a 3 hour course which taught the use of software for performing foundation, beam, column, and geotechnical design.

Two college courses used Hewlett Packard plotters. I worked extensively (1-2 years) using and red line correcting CAD generated floor plans and working drawings for mobile homes.

I have had some experience with structural truss and frame building analysis on micro, mini, and mainframe computers.

I taught CAD in school and worked with Skidmore Owings and Merrill in Denver.

I have taken a CAD couse and a course on using computers for solving and optimizing engineering problems.

I used computers as an undergraduate. They were time consuming, cumbersome, and the hardware was not dependable.

University of South Carolina School of Engineering.

IBM-Boeing Aircraft Company System/University of Idaho.

I have very little training in computer aided design, except for the computer programming required during my undergraduate schooling.

Air Force Academy: foundation design, concrete design, steel design, structural analysis, dynamic design.

Louisiana State University.

I've had a personal demonstration (1.25 hours) from a friend who works in a local Architectural firm. I think more Education with Industry (perhaps 3 months) would help officers be better designers.

I took a CAD class in graduate school.

I used computers extensively while obtaining my degree in Electrical Engineering. I've written several computer design programs in FORTRAN and PASCAL.

I have had several hours of college classes using both AHMADL mainframe and the Prime 2250 micro-computer, as well as several other personal computers and a Hewlett-Packard Drafting system.

CAD classes in college including interactive graphics load calculation on a personal computer.

College-One year course on a CAD system. Excellent course that gave great experience in it's use.

None on drafting, but I have college experience in design aid programs: pipeflow, highway design, structural analysis, etc.

1) One full semester of CADD at my university. This was not an "AutoCAD" but programs developed by faculty and students. Input modes by keyboard and digitizer allowed us to run floor plans, perspectives, object relocation, etc.
2) Reviewed Wang industries AutoCAD capabilities during a one day Wangfair.

2 courses in Mechanical Engineering design (out of 3 total design courses) which used CAD/CAM mainframe with digitizer and printer/plotter. Very effective in expediting design work and very easy to use!

In college, I used a CAD/CAM system. The projects were small because of lack of software available in the early 80's. I took a class in CAD/CAM and have taken other computer classes (FORTRAN 4 and M-77, BASIC, and some PASCAL).

1) College coursework. 2) Work at the Navy (Public Works) as a civilian Civil Engineering technician.

1) Structural aided design for the design of large beam and girder memebers (ie. strudl). 2) CAD-CAM/ Computer aided drafting and design using 3-D imagery and architectural menu selection for building layouts.

In school, Electrical Engineering requires a lot of numerical simulations, unfortunately, this is not the kink of stuff we usually use.

Courses in college: 1) Optimization simulation, 2) Fortran, 3) Computer Architecture, 4) Machine Language, 5) Assembly Language.

I had an eighteen week couse with a 3 hour CAD lab in my last semester of college

I worked for 2 years with Boeing Aircraft Company as a structural analyst We had state of the art computer equipment and the results speak for themselves- a highly successful corporation that makes a rather nice profit.

I have taken 2 classes on CAD in college about three years ago. With the advent of the personal computers, micro-computer and better computer software. mastering of computer-aided systems should only take weeks or even days.

I've used the MacIntosh system, it reduced design time in every circumstance. I have also seen a CAD/CAM system. Fantastic, we would be quantum leaps ahead of where we are now. With that type of system we could tie together all the engineers, draftsmen, cost estimating, etc. I am highly in favor of it.

I used a computer a CAD/CAM terminal extensively for two years in college and have not even had access to a computer since I've worked as a designer. All my training has been wasted because I have no equipment to use.

Appendix H: Analysis of Variance (ANOVA) Analyses

Mean Level of Question by Current Designers by Specialty

Question	Arch(a)	Civil(c)	Combined	Difference
13	-----	1.629	1.705	
14	-----	2.941*	3.000*	
15	3.667*	3.629*	3.549*	
16	3.100*	3.441*	3.134*	
17	2.300	2.371	2.195	
18	2.933*	3.086*	3.018*	
19	3.310*	3.114*	3.179*	
20	2.500	2.857*	2.620	
21	2.600	2.858*	2.646	
22	3.100*	2.912*	2.991*	
23	3.500*	2.629	2.903*	ac
24	1.700	1.314	1.345	
25	3.300*	2.800*	2.690	
26	0.400	0.571	0.407	
27	3.300*	3.400*	3.389*	
28	2.033	1.314	1.487	
29	-----	1.943	1.919	

------ population not large enough.

* significant at the .05 level.

Question	Arch(a)	Civil(c)	Combined	Difference
30	-----	2.629	2.607	
31	-----	2.686	2.652	
32	2.200	1.286	1.416	ac
33	2.800	1.486	1.796	ac
34	1.000	1.914	1.558	ac
35	2.967*	2.676	2.580	
36	0.600	0.971	0.779	
37	3.400*	3.171*	3.301*	
38	2.759	2.412	2.514	
39	2.400	2.314	2.292	
40	2.000	2.400	2.434	
41	1.167	1.714	1.628	
42	0.833	0.629	0.832	
43	2.100	2.171	2.195	
44	2.033	2.030	2.268	
45	2.300	1.676	1.920	
46	2.133	2.171	2.221	* significant at the .05 level.
47	1.000	1.400	1.301	

Mean Level of Question by Specialty

Question	Arch(a)	Civil(c)	Elec(e)	Mech(m)	Difference
13	1.936	1.556	1.854	1.750	
14	2.781*	2.914*	3.277*	3.383*	am,cm
15	3.446*	3.403*	3.277*	3.367*	
16	3.622*	3.136*	2.938*	2.741	
17	2.262	2.344	2.213	2.203	
18	2.846*	2.992*	3.021*	2.931*	
19	3.438*	2.916*	3.188*	3.050*	ca
20	2.615	2.525	2.326	2.517	
21	2.797	2 622	2.592	2.517	
22	3.047*	2.832*	3.000*	3.017*	
23	3.328*	2.740*	2.041	2.950*	ec,em,ea,ca
24	1.708	1.350	1.204	1.383	
25	3.215*	2.555	1.837	2.817*	ec,em,ea,ca
26	0.415	0.383	0.265	0.200	
27	3.185*	3.412*	3.306*	3.617*	
28	1.969	1.555	1.469	1.450	* significant at the .05 level.
29	1.688	2.160	2.312	2.217	

Question	Arch(a)	Civil(c)	Elec(e)	Mech(m)	Difference
30	2.609	2.529	2.625	2.617	
31	2.719	2.602	2.612	2.633	
32	2.215	1.275	1.204	1.083	ma,ea,ca
33	2.292	1.550	1.306	1.233	ma,ea,ca
34	1.234	2.008	1.653	1.850	am,ac
35	2.800*	2.761*	2.531	2.567	
36	0.831	1.033	0.878	0.750	
37	3.292*	3.042*	3.122*	3.183*	
38	2.703	2.427	2.204	2.467	
39	2.400	2.254	2.245	2.083	
40	2.172	2.425	2.776	2.867	ae,am
41	1.453	1.856	1.898	2.117	am
42	0.754	0.792	1.143	0.983	
43	2.200	2.117	2.271	2.068	
44	2.092	2.076	2.854*	2.017	me,ce,ae
45	2.255	1.941	1.688	1.767	
46	2.200	2.050	2.250	2.102	
47	1.308	1.353	1.479	1.083	

* significant at the .05 level.

Mean Level of Question by Current Designers
by Time as a Designer

Question	6m-1y	1y-2y	Combined	Difference
13	1.742	1.647	1.703	
14	2.968*	3.176*	3.000*	
15	3.546*	3.559*	3.549*	
16	3.182*	3.152*	3.134*	
17	1.848	2.500	2.195	
18	3.219*	3.000*	3.018*	
19	3.030*	3.235*	3.179*	
20	2.485	2.882*	2.620	
21	2.394	2.882*	2.646	
22	3.152*	2.879*	2.991*	
23	3.091*	2.706	2.903*	ac
24	1.182	1.265	1.345	
25	2.970*	2.471	2.690	
26	0.576	0.235	0.407	
27	3.2[illegible]2*	3.4[illegible]*	3.389*	
28	1.576	1.206	1.467	* significant at the .05 level.
29	2.091	1.912	1.920	

Question	6m-1y	1y-2y	Combined	Difference
30	2.667	2.471	2.607	
31	2.333	2.765	2.652	
32	1.455	1.471	1.416	ac
33	2.121	1.559	1.796	ac
34	1.667	1.441	1.558	ac
35	2.727	2.618	2.580	
36	0.727	0.706	0.779	
37	3.273*	3.235*	3.301*	
38	2.219	2.265	2.514	
39	2.182	2.206	2.292	
40	2.030	2.794	2.434	
41	1.667	1.647	1.628	
42	0.576	1.118	0.832	
43	2.030	2.206	2.195	
44	1.818	2.333	2.268	
45	1.788	1.939	1.920	
46	2.152	2.412	2.221	* significant at the .05 level.
47	1.030	1.735	1.301	

Mean Level of Question by Time as a Designer

Question	6m-1y	1y-2y	2y-3y	3y-4y	Difference
13	1.577	1.726	1.754	1.875	
14	3.038*	2.964*	3.015*	3.292*	
15	3.462*	3.306*	3.369*	3.396*	
16	3.062*	3.120*	2.922*	2.979*	
17	2.062	2.381	2.185	2.417	
18	3.050*	2.941*	2.877*	2.787*	
19	2.864*	3.047*	3.172*	3.458*	
20	2.402	2.518	2.308	2.735	
21	2.518	2.679	2.585	2.694	
22	3.085*	2.892*	2.984*	2.755	
23	2.802*	2.833*	2.876*	2.816*	
24	1.317	1.353	1.523	1.531	
25	2.728	2.659	2.662	2.470	
26	0.366	0.235	0.354	0.388	
27	3.407*	3.459*	3.292*	3.429*	
28	1.617	1.541	1.754	1.796	* significant at the .05 level.
29	2.234	2.107	2.141	1.755	

Question	6m-1y	1y-2y	2y-3y	3y-4y	Difference
30	2.667	2.488	2.672	2.429	
31	2.550	2.659	2.750	2.694	
32	1.390	1.694	1.354	1.347	
33	1.878	1.659	1.585	1.367	
34	1.815	1.619	1.646	1.776	
35	2.862*	2.588	2.769*	2.532	
36	0.793	0.835	0.969	0.857	
37	3.275*	3.047*	3.000*	3.271*	
38	2.325	2.369	2.375	3.082*	
39	2.135	2.214	2.339	2.286	
40	2.427	2.583	2.585	2.531	
41	1.914	1.795	1.846	1.714	
42	0.829	0.977	0.892	0.796	
43	2.099	2.059	2.138	2.102	
44	2.173	2.238	2.125	2.102	
45	1.778	2.083	1.923	2.083	
46	2.138	2.282	1.906	2.020	* significant at the .05 level.
47	1.175	1.377	1.339	1.224	

Mean Level of Question by Last Time as a Designer

Question	design	< 6m	1y-2y	Difference
13	1.703	1.708	1.600	
14	3.000*	3.062*	3.067*	
15	3.549*	3.333*	3 267*	
16	3.134*	3.042*	2.800	
17	2.195	2.292	1.867	
18	3.018*	2.875*	2.800	
19	3.179*	3.083*	2.900*	
20	2.623	2.480	2.333	
21	2.646	2.708	2.467	
22	2.991*	3.042*	2.793	
23	2.904*	2.917*	2.433	
24	1.360	1.583	1.267	
25	2.693	2.771	2.400	
26	0.407	0.271	0.200	
27	3.368*	3.333*	3.333*	
28	1.500	1.875	1.467	* significant at the .05 level.
29	1.929	2.085	2.000	

Question	design	< 6m	1y-2y	Difference
30	2.611	2.532	2.700	
31	2 655	2.938*	2.633	
32	1.412	1.833	1.400	
33	1.790	1.812	1.433	
34	1.570	1.812	2.000	
35	2.584*	2.750*	2.800*	
36	0.781	0.750	0.800	
37	3.298*	3.312*	3.267*	
38	2.518	2.625	2.276	
39	2.281	2 583	2.034	
40	2 430	2.417	2.500	
41	1.632	1.917	1.862	
42	0.832	1.000	0.867	
43	2.202	2.292	1.933	
44	2.274	2.375	1.967	
45	1.920	1.745	2.167	
46	2.223	2.512	1.933	* significant at the .05 level.
47	1.301	1.167	1.067	

Appendix I: Analysis of Variance (ANOVA)*

The analysis of variance (ANOVA) technique is a statistical process which is used to compare the means of populations with respect to one or more factors. The test is used to determine if one or more of the means is significantly different from the others when divided into groups by factor. (McKnight and Parker, 1983).

Similarly to the t-test, the ANOVA procedure establishes null and alternative hypotheses (Meek and Turner, 1983). For ANOVA the null hypothesis usually states that the means are all equal (Meek and Turner, 1983). This hypothesis is then tested at some significance level, usually .01 to .05, against the alternate hypothesis which says that at least one mean is significantly different from the others (McKnight and Parker, 1983). If the null hypothesis is rejected, the analyst can conclude that at least one of the means is different from the others. However, the reader should note that using a significance level of .01 to .05 means that there is some chance that there will be a Type I error (Mcknight and Parker, 1983). A Type I error occurs if the null hypothesis is rejected when in fact it should not be (Meek and Turner, 1983).

The ANOVA technique may be used to evaluate the impact of one or more independent variables (factors) on the dependent variable. The ANOVA subprogram in SPSS(X) package allows up to five simultaneous factors. In this research, however, the author was interested in only two (three) factors and their separate impacts on the means. As a result, the subprogram ONEWAY was used. ONEWAY is a standard ANOVA procedure which is run on only one factor. Hence, it was more appropriate than the ANOVA subprogram (Nie et al., 1975).

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*This appendix is reprinted in its entire form from the masters thesis of 1Lt Mark A. Correll, 1984. All citations from the original appear at the end of the appendix.

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Appendix J: Miscellaneous Survey Responses

Although I have not actively worked as a design engineer for 8 years. I have kept abreast of developments through self-study I have long been an advocate of Cadd systems in the Air Force Civil Engineering community. The design fees we so freely pay to AE firms have financed hundreds of CADD systems in the private sector, yet we have none of our own.

The Air Force is 20 years behind the times. They still think Civil/Structural engineers are maintenance technicians.

Suggest we put emphasis in providing a CAD system for the design section in all Engineering Branches at all bases. Care should be taken in allocating the Z-248 bought by the Air Force. Only those bases with real requirements should be provided for. We do not want to overcapitalize/underutilize our taxpayers dollars.

I hope the Air Force can see its way out of the stone age some day.

Architectural design in the Air Force is years behind industry standards in many ways. Technical Development is also seriously lagging behind without the computer tool in the workplace. I suggest the Air Force consider bringing their technical resources in line with civilian firm capabilities to maintain competition and enhance retention.

Hopefully, it is very obvious how a CAD/CAM system would help design. Air Force design technology is years behind the average civilian firm

I'm strongly considering leaving the Air Force due to the very limited design time I get. You cannot get a P.E. with limited design time. We send too many projects to A/E firms, while we have engineers (Air Force mainly) sitting around.

I am currently removed from my design position to work in operations. I will be leaving the Air Force as soon as my commitment is up because of this decision to move me to operations.

I sure am getting tired of all these AFIT studies (4 in 3 months).

This is the 4th AFIT survey I've done in the last 3 months.

Comment: How about publishing the results in the Engineering/Services Quarterly, or at least, a synopsis of the thesis results?

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The quantity of design, drafting, charts, and maps required by todays Civil Engineering Squadron is increasing faster than the ability of civil engineering personnel to accomplish these tasks. One possible solution to this problem is the potential for computer-aided design and drafting (CADD) systems to increase productivity of our existing manpower and pay for Architectural-Engineering (AE) contracts. This thesis determines by literature review and survey techniques to what extent officers in a base level technical design position would be able to design projects which are currently being designed by AE contract. Furthermore, this research determines the average size (designers, draftsmen, projects, dollars) of a base level technical design section. Finally, this research determines those software capabilities necessary in a CADD system for a base level design section, and determines how many CADD workstations would be needed by an average size Technical Design Section.

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