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## THESIS

CD-ROM; LIBRARY OF THE FUTURE

by

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and

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June 1988

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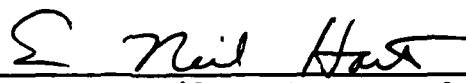
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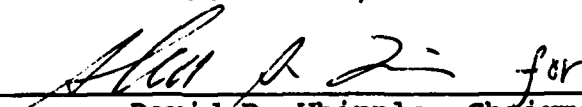
  
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### ABSTRACT

This thesis examines the feasibility of using the compact disc-read only memory (CD-ROM) as the storage medium for the Department of Defense (DOD) construction contracting. Specifically, the DOD sponsored program, headed by the Naval Facilities Engineering Command (NAVFAC), called Construction Criteria Base (CCB) is evaluated. The program is composed of a compact disc containing government construction criteria including Army, Navy and NASA standards. The test platform used is the specification branch of NAVFAC and its Engineering Field Divisions. The CD-ROM used in conjunction with a microcomputer is compared to the standards libraries of the present which are comprised of paper, microfilm and microfiche storage media. The conclusion reached is that the use of the CD-ROM disc in the DOD construction arena is advisable.



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## I. INTRODUCTION

### A. GENERAL

Laser disc technology has influenced many industries since its inception a few years ago. This thesis is concerned with the use of that technology in the Department of Defense (DOD) construction arena. It addresses the feasibility of using Compact Disc<sup>1</sup>-Read Only Memory (CD-ROM) as a library medium for storage and retrieval of construction standards. The idea to use CD-ROM as a storage medium was precipitated from DOD's desire to attack the ongoing problem of insufficient and costly data storage facilities. There is a vast amount of information necessary to design and administer construction contracts. This information is presently stored on a combination of storage media including paper, microfiche and microfilm. Maintenance and retrieval of the necessary information is time consuming and cumbersome.

Optical or laser disc technology is causing a revolution in both the private and public sectors. Their primary function has been to store vast amounts of information. Optical discs were first introduced in 1985 by the Philips

---

<sup>1</sup>The following convention on the spelling of the word, "disc" or "disk" will be used throughout this thesis in keeping with the computer industry's custom. The "c" convention referring to optical discs and the "k" when referring to magnetic computer media.



Company of The Netherlands. It has since become a multibillion dollar industry. [Ref. 1] The extent of interest that optical disc technology has created may be exemplified by the efforts of the Alexandria Institute. This is an organization located in Alexandria, Virginia which is attempting to use laser technology to capture all the world's recorded knowledge and to make it available in a container no larger than a shoebox. [Ref. 2:p. 44]

The federal government is the leading source of information and data generation in the country. DOD is a leading contributor with voluminous standards, regulations and other project data. The Department of Defense has welcomed the compact disc (CD) technology hoping to take advantage of its vast storage capacity. Its hope is to reduce space and time requirements for the storage and retrieval of large data bases.

The Naval Facilities Engineering Command (NAVFAC) has embarked on an ambitious project in cooperation with the other military services and the National Aeronautical Space Administration (NASA). The aim of the project is to provide NAVFAC's world-wide user community with easy access to all government construction standards. There appears to be much enthusiasm within the military construction community with CD-ROM's present and potential uses. The compact disc's only limits seem to be those of being at the cutting edge of technology. Breakthroughs in hardware have been so rapid in

the last two years that equipment is almost outdated by the time it has gone through the budget and acquisition process. It is, therefore, essential to properly plan for the best use of such technology if it is to be cost effective.

#### B. OBJECTIVE

The objectives of this thesis are twofold. First, the present status of the CD technology and its applications are investigated. Of primary interest is the feasibility and effectiveness of the compact disc in the construction contract arena in general. Second, construction specifications on the Compact Disc-Read Only Memory, developed by the Engineering and Design Criteria Department of NAVFAC, will be evaluated.

The evaluations are intended to serve several purposes. First, they are intended to substantiate that the benefits of CD adaptation exceed the incurred costs. Second, the evaluations are intended to study trends in CD technology in order to identify possible uses of the technology within the military construction arena.

#### C. RESEARCH METHODOLOGY

The research steps used in this thesis are:

1. Gather information on the different forms of laser technology available.
2. Identify applications of the laser technology in DOD.
3. Describe the test platform used for evaluation in this thesis.

- 4 Gather data on the test platform for a cost-benefit analysis (CBA).
5. Analyze the data, draw conclusions and make recommendations.

A more detailed discussion of the above steps is presented in the following sections.

1. Gather Information on Laser Technologies

Information on existing technology was gathered from literature found in periodicals, newspapers and other research papers. Information gathered from interviews and seminars are also used. The interviewees include the publisher of "CD Data Report," the director of the Engineering and Design Criteria Management Division of NAVFAC and other cognizant individuals. The industry is so young and in so much flux that these are the primary sources of current information.

2. Identify Applications of Laser Discs in DOD

Several examples of laser technology applications in DOD are identified. The research for these include documentation and interviews.

The DOD construction arena is of primary importance to this paper. Therefore, an outline of the contracting process will now be discussed. Construction projects are either designed in-house by DOD engineers and architects or they are contracted out for design by an Architect/Engineer (A/E) firm. The designs include a package of contract specifications and a set of construction drawings. The

entire package is commonly referred to as Plans and Specifications. The specifications are normally configured in 16 commonly used sections such as "Mechanical," "Electrical" and "Earthwork." Each section contains written instructions on how work is to proceed on the respective portion of the construction. It also identifies applicable construction standards. These standards are published guidelines for construction. There are approximately 1460 government standards and 1920 nongovernment standards commonly used in DOD construction contracts.

The plans and specifications are normally used for contract bid proposals. The successful contractor then uses these documents as the authority and guide to conduct construction projects. There are files maintained during the administration of the contract for payments, changes to the contract, etc. The plans and specifications are constantly referred to during the progress of work. At the completion of the project, as-built drawings of the work in place are maintained by the government.

### 3. Describe the Test Platform

The term "test platform" is used here to denote the DOD sanctioned project which served as a basis for the following analysis. The project is titled Construction Criteria Base or CCB. It is a DOD project spearheaded by NAVFAC. The information regarding the project was obtained from NAVFAC and its satellite offices.

CCB is a collection of construction criteria on a CD-ROM. It contains several guide specifications, design manuals and three software packages. The guide specifications are federal or military service documents which reference applicable standards for general construction categories. Design manuals contain the guidelines for designing DOD construction contracts. The software packages are for search, retrieval and manipulation.

#### 4. Gather Data for Cost Benefit Analysis

The cost-benefit analysis data is obtained from several sources. Project or equipment purchase justification report are used. Interviews and field observation results are also used. Naval Facilities Engineering Command headquarters, Western Division (one of six divisions of NAVFAC) and other field offices are used as sources of information.

#### 5. Analyze the Data

In order to analyze the data obtained, a model for decision-making is provided in Chapter V. The cost-benefit analysis is a major part of that model.

The CBA has several important steps:

1. Identify the problem: the question posed is whether the CCB is more cost effective than the existing system.
2. Identify alternatives.

3. List the constraints on the depicted scenario-political, financial, technological and other constraints need to be identified and considered.
4. Formulate the costs and benefits-there are direct and indirect costs and benefits. These must be identified and quantified to the extent possible.
5. Evaluate the results.

The decision to accept the proposed alternative should be based on the results of the CBA as well as qualitative and other relevant considerations.

## II. CURRENT TECHNOLOGIES AND APPLICATIONS

This chapter describes optical media, their origin and uses today. It gives a description of the various types of optical storage devices and presents a step by step procedure for producing a READ ONLY MEMORY DISC. The chapter also discusses the advantages and disadvantages of CD-ROM along with the hardware and software necessary to use this new technology.

### A. THE OPTICAL MEDIA IN GENERAL

Optical systems are different from the commonly used magnetic products because of their huge storage capacities and excellent data security. [Ref. 2:p. 44] The term optical disc is used because the disc is read by a laser and not magnetic heads.

Optical discs make it possible to cheaply squeeze reams of digitized data-sound, pictures or text information into a small area. A normal five and one quarter inch optical disc can hold as much data as about 1500 floppy magnetic disks, or 270,000 pages of text. [Ref. 2:p. 44] Figure 1 further illustrates the comparative capacities of CD-ROM and other storage devices. In an optical disc, data is stored in submicroscopic pits or spots in the reflective surface of the disc. A pit is a microscopic depression in the

# **CD-ROM: MASS STORAGE DEVICE**

- **ONE CD-ROM STORES THE SAME AMOUNT OF DATA AS....**
- **270,000 PAGES OF TEXT**
- **1,500 5-1/4" FLOPPY DISKS**
- **20,000 PAGES OF 300\*300 DPI IMAGES OR**
- **27 20 MEGABYTES WINCHESTER DISKS**
- **10 STANDARD 1/2" 9-TRACK MAGNETIC TAPES**
- **1200 MICROFICHE CARDS**
- **ONE HOUR OF FULL-MOTION, FULL SCREEN, FULL-COLOR DIGITAL VIDEO**
- **1,104 HOURS OR 46 DAYS OF DATA TRANSMISSION AT 1200 BAUD**
- **10,000 PAGES --1/2 TEXT AND 1/2 GRAPHICS**

**SOURCE DDRI**

**Figure 1. CD-ROM: Mass Storage Device**



reflective surface of a CD-ROM representing two or more bits depending on the length, or run, of the pit (see Figure 2).

There are three categories of optical recording media: read-only, write-once and erasable (see Figure 3). Understanding the formats of optical technologies and their individual uses is the initial step in implementing them. The basic differences among the three formats, shown in Figure 3, are as follows:

1. Videodisc and CD-ROM are read-only media formats. In this format, data is encoded onto a master disc at a manufacturing facility and duplicate discs are produced from the master. The data on the disc can only be altered by remastering and reduplicating.
2. Optical disc is a write-once medium format. Data is encoded or recorded onto the disc at a local workstation, local area network, or in a distributed computing environment, in a manner similar to copying onto a floppy disk, or mainframe storage.
3. Erasable or rewritable disc is not yet offered commercially. Once it is commercially available, it will allow one to write, modify, erase, or rewrite on a disc, similar to what is currently done on a floppy disk with a microcomputer.

Today, laser discs are used in a variety of forms encompassing motion picture, sound and text data. They are used by many industries including entertainment, private business, government, education and personal home use.

There are 12 inch videodiscs, which essentially substitute for VHS/BETA tapes, claiming superior picture and sound quality. All major electronic industries are producing Audio Compact Discs and Compact Disc(CD)-players. Competition and improvements in technology have reduced the average

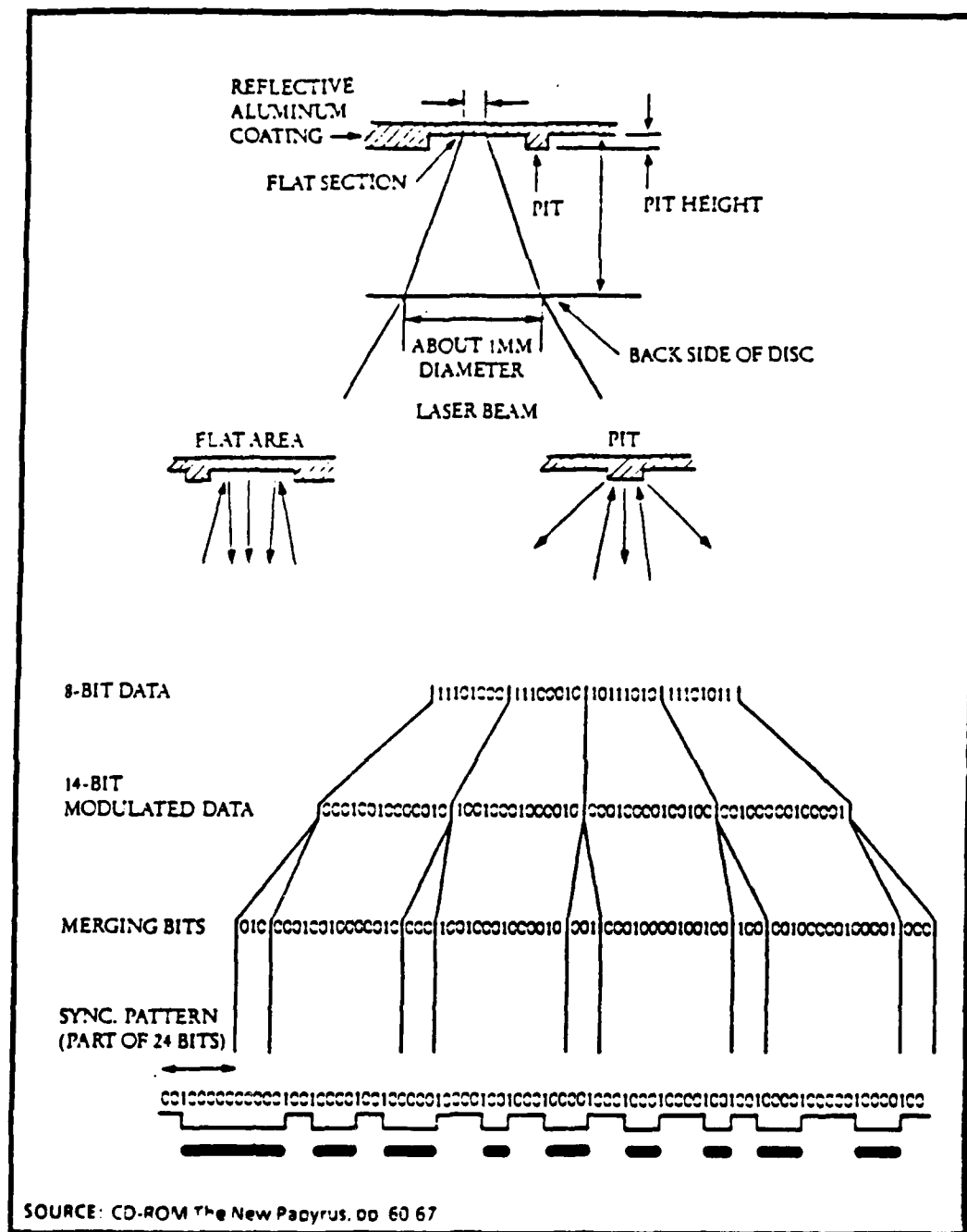


Figure 2. The Conversion from Bits to Bytes

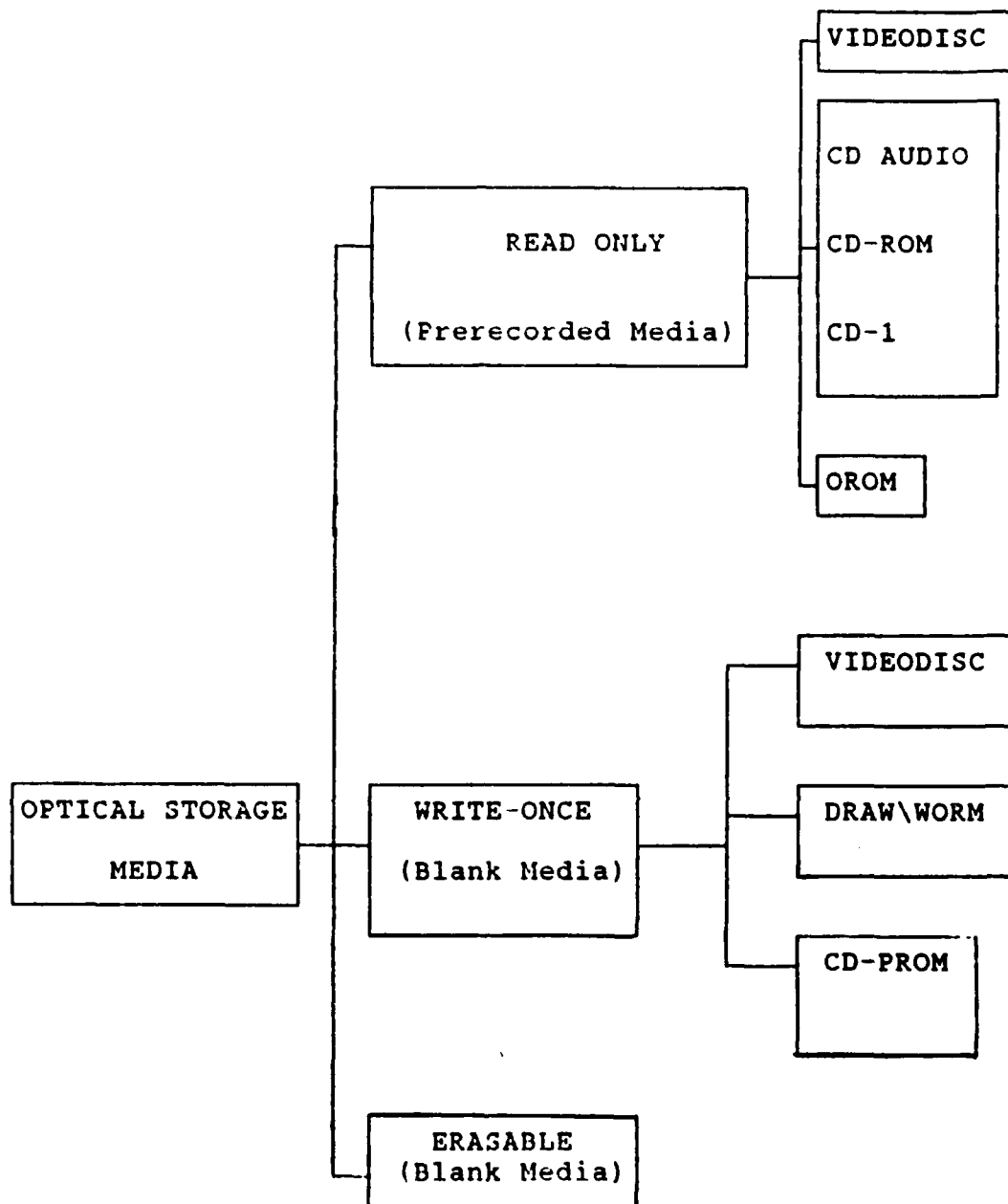


Figure 3. Optical Storage Media

price of CD-players 50% Many brands are being sold for under \$300.

Compact disc technology was developed by the Philips Company, N.V. and the Sony Corporation. The technology is licensed worldwide by more than 100 companies. Using this technology, the compact music disc (CMD) was developed and introduced in 1982. The CMD offered a dramatic improvement in the quality of recorded sound. Several million players and more than 70 million compact music discs have been sold. [Ref. 3]

On the data processing side, there are a number of microcomputer-based integrated systems available today which offer the capability for scanning and storing documents on optical disc. The hardware may differ from system to system, but the basic components are the same. The configuration includes a high-resolution monitor and scanner, a laser printer, optical disc storage device, and a host system (i.e., IBM,PC) usually operating under an MS-DOS operating environment. Such integrated filing and retrieval systems can reduce the massive accumulation of paper files by storing them on optical discs. Common to these systems are simple indexing schemes to quickly tag documents by a few fields for future retrieval. Discs used in conjunction with microcomputers can have image as well as text capability. Processible images appear in CD-ROM information

products. Reference-image databases are currently being developed.

Scanners are available which read text and images as a first step to transposing the data onto discs. These will be discussed further in the hardware section that follows. However, a few general notes are made here regarding scanning and storage of images. It takes a lot of room to store an image in digitized form. The rate at which an image can be copied from the disc into the microprocessor is slow, compared to magnetic disks. One byte is approximately equal to one ASCII<sup>1</sup> character.

Images are made up of dots. Each dot must be described and stored separately. The more dots there are, the more room is required to store the image. Thus, the more detail required, the more room an image occupies on the disc. A range of 150 to 400 dots-per inch (DPI) is currently used. At 400 DPI, a quality replica of a complex drawing is delivered. One such image requires about two million bytes of space. Since a disc holds 540 million bytes, one could store 540/2 or 270 images in this form on one CD-ROM disc.

Image compression technology is available, which essentially captures the same information, but uses only

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<sup>1</sup>There are 256 ASCII standard characters stored in the computer's permanent read-only memory. The ASCII set includes the English alphabet and the ten decimal digits. Also included are many foreign language symbols, two smiling faces, arrows, playing-card suite characters, et cetera. One or two of the ASCII symbols are used as the familiar blinking cursor symbol itself.

half the storage space. One such coding scheme is called run-length encoding. Depending on the image and the resolution level required, images can be "compressed" 10 to 50 or 60 times. It has been found that 270 of the 400 DPI images could be stored on a disc in a "raw" state. If those images are compressed by a factor of ten, 2700 compressed images can be stored on a disc. A drawback of compression is that it increases retrieval time by about 20%. This represents the time needed to decompress the image. Coding systems are also subject to errors.

A few statistics give insight on the turbulent situation in the CD industry. In 1984 there were five CD plants with a total production capacity of 700 million discs. [Ref. 4] Additionally, there were 29 CD-ROM related industry and professional conferences between September 1987 and March 1988. [Ref. 5]

## B. READ ONLY MEDIA

### 1. Product Description

In order to see the advantages and disadvantages of the read-only media, it is necessary to understand the essentials of the industry and the product.

Prerecorded discs are used in the entertainment and business sectors. The recording format is a spiral groove about three miles long. The tracking is maintained by the constant linear velocity (CLV) technique which requires variation of the disc rotation speed based on the distance

of the read head from the center of the disc. Quality discs can be mass produced after a glass master is created. This makes the prerecorded discs excellent candidates for the entertainment industry, for distribution of large databases and permanent archival record keeping. The primary concern of this paper will be in reviewing the wisdom of applying this technology to databases and archival records, particularly within DOD construction.

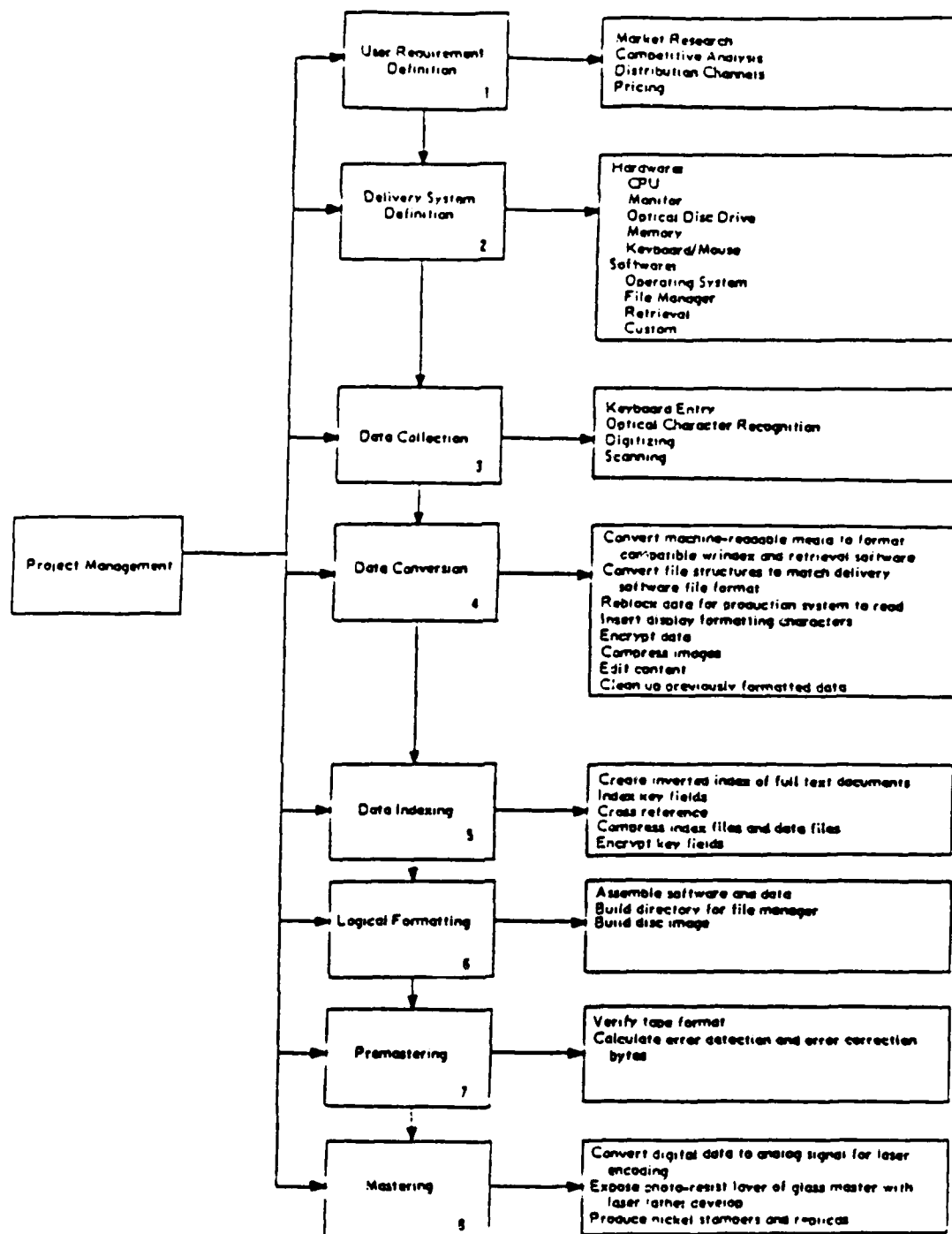
Before any discs can be manufactured, some standard must be in place. In the size category, the 4.72 inch (120mm) disc is the popular standard in use today. Software and hardware are, therefore, adapted to this standard. Formatting and encoding standards are not yet universal. Varied and proprietary methods are in use. This causes problems with compatibility and interoperability.

## 2. Production Procedure

There are eight steps in the process of producing a prerecorded disc. Figure 4 shows the typical CD-ROM production process.

### a. Step One: User Requirement Definition

This step is very important. The user's needs and desires must be balanced with both competitive analysis and production costs. It is essential that an analysis be conducted before delving into the lengthy and costly process of producing a CD-ROM. It is necessary to compare the costs of the status quo with those of purchasing the database from



SOURCE: Reference Technology Inc., Boulder, Colorado

Figure 4. Application Development Process for a CD-ROM Product



a vendor, if available, and those of producing the product in-house.

b. Step Two: Delivery System Definition

The most effective system of software and hardware<sup>2</sup> is the prime goal of the compact disc industry. Some specific items of consideration are listed in Figure 4. In choosing the most effective system, it is important to remember that efficiency and cost cannot be optimized simultaneously. One can choose a desired level of efficiency and minimize the cost of that purchase. Conversely, one can choose a budget amount and maximize the amount of efficiency or effectiveness purchased.

c. Step Three: Data Collection

The various methods of data entry must be considered. Although data can be entered via an operator on a keyboard, it is more typically done by the use of scanners. Scanners are available for a variety of needs to transfer text and pictorial data without the use of keyboards. Quality, cost and timing are some of the factors that should be used for comparison.

d. Step Four: Data Conversion

Data must be converted into machine readable language. Information is typically stored on half inch

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<sup>2</sup>Software constantly precedes hardware in this paper to emphasize the lessons learned highlighted in most publications on the subject. The software should be based on the user's needs while the hardware should accommodate the software.

magnetic tape before being processed into a laser disc. The conversion is a necessary step. The complexities of costs to convert data residing in different formats should be considered here. The information may be text, drawings or pictures and may be maintained on paper, microfilm, microfiche, tape, or floppy discs. The full range of these options are listed in Figure 4.

e. Step Five: Data Indexing

Data indexing is important for the future retrieval of the information. Large data files should be indexed to reduce the retrieval time necessary to search for required information. Indexing involves a variety of tasks including key fields, cross references, compressed data and encryption. Uniform standards are not employed throughout the government and construction industry which is increasingly recognized as a growing obstacle to interoperability.

f. Step Six: Logical Formatting

During this step the software and the data of all associated indices is assembled. Directories are also prepared at this time.

g. Step Seven: Premastering

Premastering is done by the publisher. It involves transferring the data to half inch magnetic tapes.

#### h. Step Eight: Mastering

Mastering typically takes place at a disc factory in a clean environment. The tapes are converted to a glass master using a high powered laser. From the glass master, a negative impression is taken to make a "metal-mother." This is used to make multiple replicas which are then coated with a layer of metal oxide lacquer for protection. The present trend is toward vertical integration of services via the combination of premastering and mastering within one company.

#### 3. Advantages and Disadvantages

The primary advantages of prerecorded discs are their durability, size and data storage capacity. The durability eliminates the need for duplication as is the case with floppy disks. It also allows for ease in handling without the fear of losing data. Together, the three traits make the prerecorded discs ideal for dissemination of voluminous data with an update cycle of one month or more. An example of this is published government standards. Figure 5 lists additional advantages and disadvantages.

The read-only capability is the primary disadvantage of the discs, particularly, if the user wishes to change the data at the working level. This disadvantage can be a benefit as well depending on one's perspective. If one wants standards to be universal with no possibility of someone altering the data. An example would be if the

## **ADVANTAGES**

- **PERMANENT/DURABLE:** It is an excellent archival medium (currently Sony disks are guaranteed for 50 years.) Also very rugged and able to withstand adverse weather and handling conditions.
- **NON-VOLITATILE:** No loss of altering of data during power failure or surges.
- **LOW COST:** The 'per MB' cost of data is less than any storage medium.
- **EXTREMELY PORTABLE:** The media is removeable and offers portability of data.
- **SECURITY:** Physical control can be maintained easily and thus large quantities of sensitive data can be controlled. Also, the possibility exists to manufacture the disk out of glass instead of polycarbonate material and thus, for military purposes emergency destruction could be easily accomplished.
- **SMALL PHYSICAL VOLUME/WEIGHT:** Easily carried, or mailed etc, at a very reasonable expense.
- **NOT ABLE TO BE ALTERED:** This media is Read Only Memory (ROM) and as such, it is extremely useful for audit trails in the legal and financial world where magnetic media have not been allowed as evidence due to the alterability of that media.
- **ENORMOUS DATA STORAGE CAPABILITY:** Up to 600 MB of data on a single side of a single disk which is only 4.72 inches in diameter.
- **USER FAMILIARITY:** It is simply another PC peripheral that, to the user, looks just like a read only MS-DOS etc. disk. Also, the average user has had experience with the same physical disk in the CD-Audio environment and therefore feels more comfortable with it all ready.
- **BACKUP IS ELIMINATED:** There is no need to backup the disk because it is ROM. For safety sake, multiply copies can be ordered at the time of disk pressing and stored in separate locations.
- **ELECTRO-MAGNETIC PULSE (EMP) HAS NO EFFECT:** This is not a magnetic media and therefore any sort of electro-magnetic energy has no effect on it.
- **NO HEAD-CRASHES:** The read-device is optical and does not contact the disk in any way, therefore, head-crashes are virtually eliminated.

Figure 5. CD-ROM Advantages and Disadvantages

### DISADVANTAGES

- **READ ONLY:** This feature, while a benefit to some is a hindrance to others desiring to alter their data.
- **INITIAL COSTS FOR ADDITIONAL HARDWARE:** Although this is true of any new system, it is viewed by many as a disadvantage when compared against the all ready sunk costs of the presently installed system.
- **SLOW ACCESS SPEEDS:** The average time to retrieve data, when compared to hard disk etc. is much longer.

	<u>Floppy Disk</u>	<u>Hard Disk</u>	<u>CD-ROM</u>
Storage Capacity:	360KB-1.2MB	10MB - 70MB	540MB
Revolving Speed:	300 RPM	3,000 RPM	200-500RPM
Access Time:	100 msec	28-70 msec	0.4-1 SEC.

Note: Backup of 10M of data from hard disk onto floppy disks can take up to 1 hour.

Figure 5 (Continued)

distributor is a central agency who is disseminating standards to subordinate users, he may prefer the ROM feature. Conversely, the subordinate user may prefer to tailor portions of the data for his local needs and have the ability to write on the disc. Figure 6 lists the major premastering and mastering firms. The information shown in Figure 6 is based on results of a survey conducted by CD Data Report published in May 1987. [Ref. 6]

### C. OPTICAL WRITE-ONCE MEDIA

The common abbreviation for "write once read many" is WORM. Unlike CD-ROM and other read-only media, write-once optical media provide the capability of recording information onto a disc at the local work station. Like read-only media, optical disk technology allows the user to read the stored recorded data from a disc. With the writable optical disc systems, however, a single laser with two intensities (or two different lasers with two different intensities) are used for both recording and later reading in a single drive.

Discs in this area come in a variety of sizes and formats. Systems are usually sold as an entire package and lack interoperability with other systems. The discs are generally five and one quarter inch in diameter and are two sided containing approximately 200 MegaBytes of data per side. Other sizes of discs are also available ranging from three and one half inches to 14 inches.

Premastering Firms	Input Data Base Size	Fees	
		3 Day	10 Day
Discovery	700 MB	(1)	(1)
Digital Library System	4 GB	\$5800	\$4700
I S/R Systems	Unltd.	-	-
Laser Gmbtt	700 MB	-	-
Meridian Data, Inc.	7200 MB	(2)	(2)
OnLine Computer Systems	Unltd.	Quote	Quote
Publisher Data Service Corp. (PDSC)	900 MB	\$2650 (3)	\$2650 (3)
Reteaco, Inc.	Unltd.	(4)	(4)
Silver Platter Info., Inc./(UK)	900 MB	Varies	Varies
Silver Platter Info., Inc./(US)	Unltd.	Quote	Quote
Sonopress Gmbh	-	(5)	(5)
Taunton Eng. Inc.	552 MB	\$2000	\$2000
TMS, Inc.	-	\$2495	\$2495

#### Mastering Facilities

Digital Audio Disc Corporation  
Discovery Systems  
Hitachi Corporation  
Philips and Dupont Optical  
Sonopress Gmbtt  
Sony Corporation  
3M Company

- (1) Discovery Systems' charge for premastering is included in mastering fee.
- (2) Meridian Data Premastering Costs: \$500 setup charge; \$250/hour with operator; \$100/hour without operator.
- (3) PDSC premasters tapes for DADC for \$7300 (10-day turn) and \$9000 (3-day turn).
- (4) Reteaco, Inc., provides premastering, indexing, the FindIt software system and mastering for \$9995.
- (5) Sonopress' charges: For premastering-DM 1,990 (<100 MB) or DM 3,890 (>100 MB). Mastering is DM 4,980. Sur-charge for turnaround time less than 15 days.

Source: CD Data Report, Vol, No. 7, pp. 19,20,  
May 1987

Figure 6. Sample of Premastering Firms

The optical write-once medium offers certain advantages and disadvantages (see Figure 7). It has most of the advantages of the read-only medium regarding high volume data storage which is safe, reliable, durable, rugged and long lasting. However, once the data or image is placed on the disc, it is permanent. Updates require reentering the entire data over again onto a new disc or onto the yet unused portion of the existing disc.

An added benefit is that it is cheaper to have a desk top system of mass data storage than to maintain a mainframe computer. It also eliminates all the space requirements of paper. The disadvantage is the proprietary nature of the systems due to a lack of standards. No two systems on the market are alike. The disc used with one company's drive cannot be used on another company's system.

An appropriate usage for this storage media is archival data. Updates are not necessary and pose no problem.

A closely related application would be the storage of engineering drawings and specifications. One must keep in mind the problem of updating information. As such, only archival plans and specifications such as as-builts of completed projects would be good candidates.

Another application of WORM is as an intermediary step to the read-only disc production, which can then be mass distributed. Many of the companies listed in Figure 6 can



### ADVANTAGES

- \* DESKTOP MASTERING: Information can be placed on the disc by the user.
- \* PERMANENT/DURABLE: It is a good archival medium, rugged and able to withstand adverse conditions.
- \* PORTABLE: Data is stored on a disc.
- \* SECURITY: Physical control of the disc can easily be maintained.
- \* SMALL PHYSICAL VOLUME/WEIGHT: The disc is 1.2mm thick and weighs about one ounce.
- \* LARGE DATA STORAGE CAPABILITY

### DISADVANTAGES

- \* LACK OF STANDARDS: Various formats due to the lack of industry-wide standards limits use to specific areas.
- \* SLOW ACCESS SPEED: Large data volume can cause retrieval to be slow.
- \* LABOR INTENSIVE MAINTENANCE: Entire data must be reentered when updating due to non-erasable characters.

Figure 7. Write-Once Media Advantages and Disadvantages

accommodate this type of data input in lieu of magnetic tape.

#### D. ERASABLE MEDIA

Erasable optical storage is not yet a viable product. When it is a commercially acceptable product, it will closely resemble the features we have learned to expect in

magnetic storage media. The added features will be those presented previously for the other two media.

Expected targets would be professional workstations where the discs would act as large capacity notepads with up to 350 megabytes of storage space.

#### E. CD-ROM HARDWARE

Hardware is only one part of the Optical Information System (OIS). The growth in the industry has been so rapid that much of the information presented here was acquired from seminars, interviews, magazines, newspapers and other publications.

The optical information system is revolutionary in that the "central information file" (CIF) concept, can conceivably become a reality. It is appealing to have the ability to use optical technology to store and to link paper files, such as construction standards, with computer data in a single system. The added ability to retrieve and display that information on an isolated and decentralized terminal workstation enhances efficiency through reduced retrieval time. The present society desires to have questions answered as quickly as possible. Government is a business and must make use of new technology whenever it seems to be efficient and cost effective. As the largest producer and user of information, the government is very interested in making large amounts of information accessible and easily retrievable. Centralized data with decentralized user

stations make sense for use by the Department of Defense. An example is a construction project in the remote island of Diego Garcia. The project manager ideally needs to have access to all the construction standards that are called out in the construction contract being performed. However, it is impractical and costly to have available the volumes of standards necessary to accomplish this task. It is also impractical to have this information centrally located and disseminated by mechanical links to such a remote site. The turnkey optical system is able to accommodate this situation by efficiently providing the information on a disc. The rest of this section examines the hardware which allows one to use these laser discs.

The workstation/terminal is the primary hardware of the laser disc user. The personal computer (pc) is the primary mode of information display and use. Presently, there are microcomputers produced with built in compact disk drives. The portable compact disc reader accommodates those PC users who do not have a compact disk drive built in to their microcomputer. A laser printer adds the best printing capability to the system.

The recommended systems are IBM compatible using an image compression board which uses a standard DOS file format. This allows movement of compressed images to and from any component hardware on the system. The use of the industry standard interface, Small Computer Standard

Interface (SCSI) to the equipment components, the use of a DOS file standard for image storage and delivery, and the use of Consolidated Committee of International Telephone and Telegraph (CCITT) communication standards make this class of system totally compatible with computer industry trends. Recent hardware announcements by firms such as Apple may carve niches in the IBM compatibility arena.

#### 1. Present Situation of Hardware

There were about 25 million personal computers in the United States in 1987. Of those, 400,000 were within the federal government. This is double the 1986 figure. The expected worldwide annual sales of PC's is three to four million. Libraries are a large user of microcomputers. There are about 50,000 PC's in use within the 80,000 libraries in the United States. [Ref. 7] Additionally, there are an estimated 50,000 CD-ROM drives in use today. [Ref. 8]

Apparently, the CD-ROM manufacturers see the growing demand for their technology within the microcomputer field. This is evidenced by the differences in the products seen at the 1988 Microsoft Corporation, CD-ROM conference. Computerworld, a news publication, reports that the conference shows in 1987 focused mostly on ideas about the "gee-whiz" potential of CD-ROM. In 1988, the shows related the pragmatic nature of commercial services and products available. [Ref. 9] The Apple Company apparently dominated

the conference with the introduction of "CD SC," its \$1,199 CD-ROM drive. Some other product introductions included Hitachi Corporation's CD-ROM drive available in June 1988 costing \$1500, and Meridian Data, Inc.'s network CD-ROM drives and data bases to be integrated into an IBM Token-Ring, Ethernet or Arcnet LAN. The Meridian "CD-Server" became available in April 1988 for \$5,995. [Ref. 11:p. 116]

In general, CD-ROM drives for IBM PC's are made by such companies as Sony Corporation, Hitachi Sales Corporation of America, Amdek Corporation and others. Their prices range from \$700 to \$1200. Current expectations are for prices as low as \$500 in the near future. Microsoft's Chairman, Bill Gates, predicts that by 1991, a CD-ROM drive could become standard with every \$1,000 personal computer. [Ref. 8:p. 1F]

The following list of currently available hardware represents the state of hardware technology today. It is being presented to show the numerous differences in both type and cost of hardware available today.

1. Docutron 2000 is an Electronic Document Management System made by 3M. It combines digital scanning, laser writing and reading with optical storage and also produces high resolution copies. [Ref. 10]
2. CD-ROM Drive by Amdek Corporation is designed to fit into a slot for a floppy drive on IBM-compatible computers. Its cost is \$895. [Ref. 11]
3. CD-ROM Drive Player by Atari Corporation connects to Atari ST or Mega Computer through a built in port and will be available in June 1988 for \$599. [Ref. 6:pp. 19-20]

4. Hitachi CDR-1503S has a CD-ROM drive with 552-MB memory capacity. It is the second generation drive with a two channel audio output. It is designed for use with IBM PC/XT/AT and must be connected to an interface cord that slots into an expansion slot of the personal computer.
5. Philips and Control Data, Joint Venture CM 200 series drive has 600 megabyte (Mbyte) memory capacity disc drive. This drive is part of the 5 1/4 inch half-height series.
6. Topix is a desktop optical disc publishing system developed by Optimal Media International. Features include editing, file structure creation, simulation and premastering for standard or multimedia CD-ROMs and write-once optical discs. The Write-Once optical disc sub system is available for cartridges up to 1.2 Gigabyte capacity. The system price starts at \$12,995.
7. Panasonic's Optical Memory Disc Recorder (OMDR) may be used to create an image bank, or interactive videos with two-channel sound and on-screen type editing.
8. Meridian Data, Inc.'s CD Master reportedly allows a CD audio mastering facility to expand into a complete CD-ROM, CD-I (interactive), Digital Video Interactive (DVI) prep and premastering facility. The cost is \$89,750.
9. Custom Design Technology, Inc. has three products the portable computer, the external CD-ROM drive and the internal CD-ROM drive. The 17 inch wide by 8 inch high by 17 inch deep, 29 pound portable computer comes with a floppy disk drive and a CD-ROM drive and sells for \$2995. The external CD-ROM drive sells for \$705 and the internal one for \$610.
10. Danton Caccuum, Inc. has the DiscLine-500. It can reportedly metalise 500 discs per hour. It has a built in clean air system and laminar hood which eliminates the need for a clean room. The price is \$244,840.
11. Groupe Electrocom Group, Inc. of Montreal has come out with Workstation Versatility. This Canadian government sponsored group has assembled a workstation that combines an IBM PC (or IBM compatible), a laser video disc player, a touchscreen and a CD-ROM drive.  
[Ref. 12]

## 2. CD Hardware Trends

Since the growth and development of CD's is related to the sale of microcomputers, the projected growth of the microcomputer along with that of compact discs is included in Figure 8. The anticipated growth displayed in Figure 8 is based upon assumptions made by Philips and DuPont Optical. Their assumptions vary from economic indicators in the United States to such things as public and not-for-profit institutions roles in the European electronic information industry. [Ref. 7] Projections of growth for the United States appear to be strong enough to recommend continued government involvement in laser disc technology. The costs and benefits of laser disc technology use in the DOD construction arena is discussed in Chapter V.

The remainder of this section will focus on trends in the technology and the production of laser discs. The emphasis will be placed on the possible uses for CD-ROM in defense construction.

Write-once technology continues to grow despite problems with lack of standardization and other disadvantages listed previously in this chapter. This may be due to the lack of commercially available read-write technology. Write-once technology is being increasingly used for desktop publishing of large data files and mastering of discs. AGA's DISCUS 1000 is an example of a system which allows

# CD-ROM DRIVES WORLDWIDE SALES

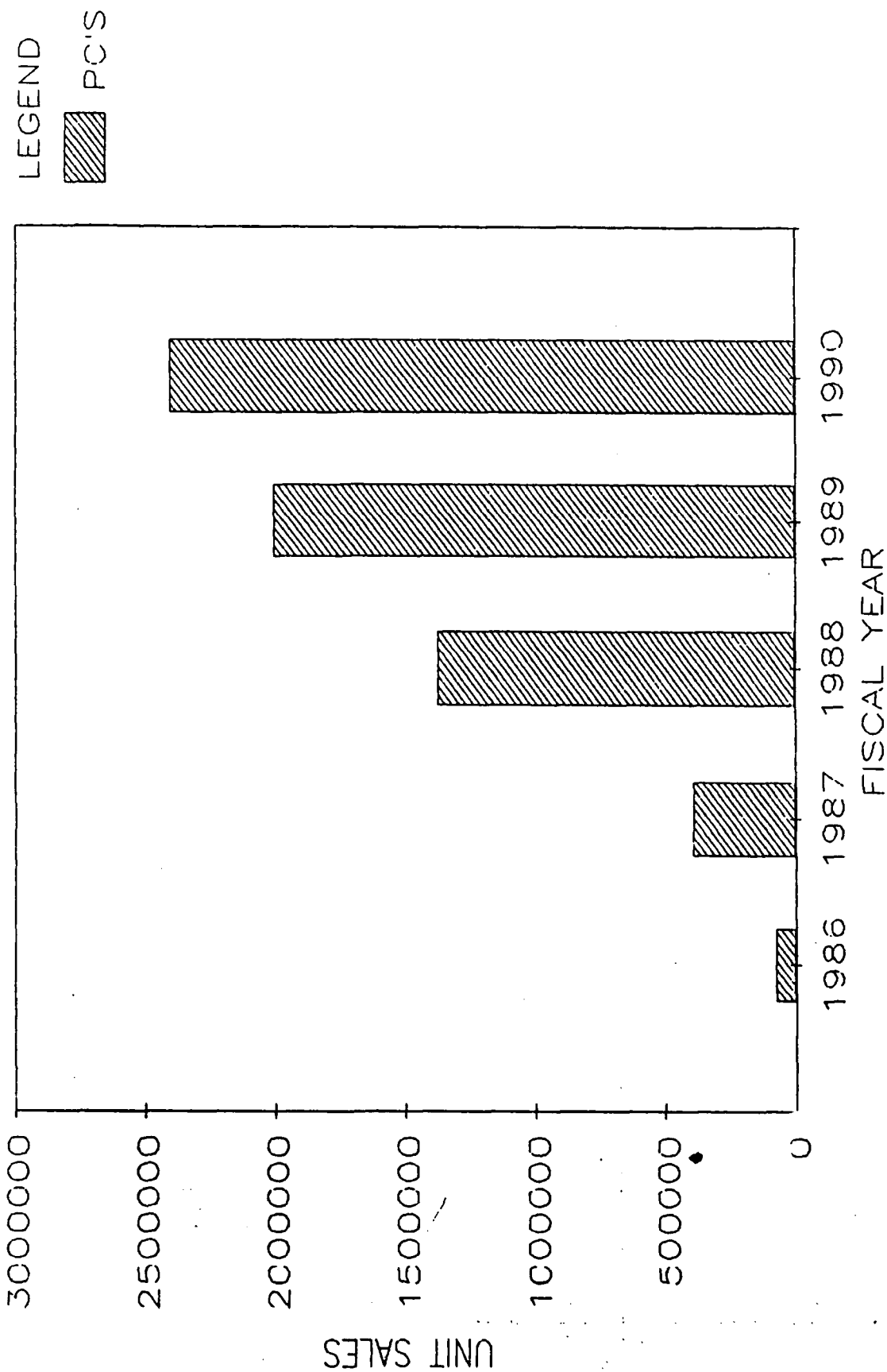


Figure 8. CD-ROM Drives Worldwide Sales



users to premaster their own information using any DOS-based applications. The data is then directly transferred via the 12 inch disc to 3M for mastering. [Ref. 13]

There is increased vertical integration in the CD-ROM production. As products such as the ones described above are made available, the mastering houses find it profitable to combine premastering within their business. This trend should lead to a user produced disc in a single location.

Future use of laser discs will require even greater storage capacity, particularly when dealing with non-test images. Workstations with combinations of laser technology and the PC are becoming commonplace in the business world. One reason for this trend is a videodisc can hold about 54,000 images in comparison to a CD-ROM which can hold only a few thousand. Another method of increasing capacity is the "jukebox" storage system which can store multiple CD-ROM's and access them quickly by mechanical means. This is an area of growing interest and development. It is expected that by 1989, jukeboxes capable of handling over 100 discs, will be available commercially. [Ref. 14] The desired trend is for a single universal or multifunctional drive capable of handling several different discs.

#### F. SOFTWARE

The information presented in this study emphasizes the use of CD-ROM as opposed to the other optical technologies.

This is because CD-ROM constitutes the majority of new product announcements within the business and education communities. Additionally, this study will assess the current use of the CD-ROM within DOD construction. It is important to understand what software is available commercially for use with CD-ROM and its application. Then one can better assess CD-ROM's present and future use in the construction arena. One cannot and should not ignore the other forms of optical technology. Understanding the technology's present use and future potential will ensure more effective and efficient use of it.

In the Management Information Systems (MIS) arena, there is much discussion about centralization versus decentralization. For example, centralization is believed to make large data bases accessible to many remote users. Centralized systems have normally required a method of storing large amounts of data in such places as a main frame computer. They also require interoperative tie-ins, access codes and remote terminals which are governed by their links to the central terminal. Proponents of decentralization prefer the autonomy of an independent workstation. However, they have had to give up access to large data bases when working independently.

The optical information system is revolutionary in that the "central information file" (CIF) concept, a goal of computer technology from its inception, is finally possible.

The ability to use optical technology to store and link paper files and computer data in a single system and retrieve and display that information on a single terminal workstation will offer a greater potential for productivity gains. The turnkey systems of today can scan, digitize, store, index and retrieve documents presently maintained in file cabinets and bookshelves. The major concern therefore surrounds software. There are a growing number of CD-ROM software packages commercially available currently. However, standardization issues lag behind profit issues. The products are generally proprietary and incompatible with each other thus diminishing their future potential.

#### 1. Present Situation

The most prominent sectors of laser disc technology involvement have been in the government, libraries and businesses.

The governmental agencies with their large data bases and vast geographic boundaries appear to be natural clients. There have been several efforts within DOD, as well as by private contractors using DOD information, to utilize CD-ROM in a variety of areas, particularly in logistics. An example of this is NAVSEA's efforts in data distribution to the fleet through the Ships Configuration

and Logistics Support Information (SCLSIS) program. The CD-ROM discs were made for NAVSEA under an 8(a)<sup>3</sup> contract in the latter part of 1987. The first, Ship Configuration and Logistics Support Index #1 contains 400 plus Mbytes of data or 700,000 records, including the Master Index of Allowance Parts Lists (APLs), the Expanded Ship work Breakdown Structure, the Service Applicability Code, and Equipment Identification Code (EIC). Positive aspects of this system include timely and synchronized data. Timeliness refers to the speed of retrieval and ease of searching. Having information easily accessible allowed NAVSEA to discover problems inherent in the original data. Lack of consistency in the raw data has caused problems with data indexing, conversion and later retrieval on the CD-ROM. With a straight dump from the mainframe, it was not possible to see data anomalies. A negative aspect, later corrected, was the incompatibility of the proprietary drivers with MS/DOS extensions. The lack of commercially available and industry-wide accepted MS/DOS extensions had caused companies to produce incompatible products prior to 1988. This relates to the standards issue which will be addressed in the next section. [Ref. 15]

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<sup>3</sup>8(a) is a nickname for minority set-aside contracts. It is derived from the particular paragraph found in the Federal Acquisition Regulations (FAR) which addresses such negotiated contracts.

Another example of DOD application is the United States Air Force's Prototype Acquisition Library Disc. This is a CD-ROM developed as a broad-based library of necessary documents to civilian and military personnel responsible for acquisitions through the Air Force System Command (AFSC). The project is sponsored by the Computer Resource Management Technology Program Office (CRMT) whose role is to investigate and research the latest technology in industry, academia and laboratories, and to develop prototype projects where appropriate. During the disc prototype phase, CRMT will supply requesting government agencies with the necessary CD-ROM equipment and quarterly updated discs for \$500 to \$900. [Ref. 16]

Libraries have been prominent users of the laser disc technology both in the U.S. and abroad. Their vast data bases make them an ideal customer. Libraries have undertaken several projects which have proven to be successful. One such project is the Monterey Bay Area Cooperative Library System (MOSAC).

MOBAC is a federally funded (\$148,000 grant) pilot project for fiscal year 1988. Its purpose is to demonstrate the feasibility of using CD-ROM technology to promote resource-sharing among public, academic and special libraries in the Monterey Bay Area in California. The idea is to create a combined catalog of assets in all eight participating libraries so that they can be shared. The

initial set of 25 discs issued in the summer of 1988 will have embedded software for Boolean<sup>4</sup> operation using any number of parameters such as title, author, subject, and year of publication. Search time will vary from less than one second to 30 seconds for extensive projects. [Ref. 17]

The business industry has a vast number of CD-ROM projects. Some of them are included in the list provided below. The list provides some examples of the type of efforts currently being undertaken.

1. American Airlines' Sabre reservation system: This venture was announced by Spectrum Interactive, at the March 1988 Microsoft Corporation sponsored conference in Seattle. It will use the IBM Personal System/2 and digital audio/ video to add the feature of showing customers high resolution color images of vacation spots and hotel rooms. The reservation system is used on about 60,000 terminals.
2. The United States Postal Service (USPS) replacement of mainframe with CD-ROM: In March 1988 the USPS switched its mainframe based zip code retrieval system with 438 CD-ROM drive systems. The expected cost savings per zip code retrieval will be 50%. Ironically, a month later, the prices of posting mail increased. [Ref. 9:p. 116]
3. A Directory of Library and Information Professionals: A CD-ROM using data retrieval Software from Knowledge Access International. Price is \$495.
4. Complete Home Video Directory Plus: A CD-ROM disc made by R.R.Bowker. It contains over 20,000 motion picture releases retrievable by a variety of ways such as title, performers and rating.
5. Oxford English Dictionary: Price of CD is \$1250.
6. Books in Print Plus: Price of CD is \$995.

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<sup>4</sup>Boolean basically refers to the ability to query using similar to an expert system. One is therefore able to search for "this or that" simultaneously.

7. Library of Congress Catalog Distribution Service's (CDS) LC Autorities: The single disc is available as of April 1988 for about \$300 with monthly updates.
8. Silverplatter makes 14 CD-ROM titles: The titles range in subject and price. Some of the titles are CANCER-CD, CHEM-BAND, COMPU-INFO, MEDLINE AND PSYCH LIT. The prices range from \$650 per year to \$3,995 per year with quarterly updates.
9. Standard and Poor's COMPUSTAT II: Contains 10,200 companies. The Software developed by Marnick Associates allows the user to set up value ranges for several criteria in order to extract a subset of companies. The user can then design reports including data elements, such as income statements and ratio reports. Users can edit the data and add to the database or export the work to Lotus 1-2-3. The Price is \$8000 per year.
10. Personal Library Software (PLS) retrieval software: This is a text search and retrieval software which has the embedded capabilities of Microsoft's WIndows2.0. It is capable of running on a mainframe or a microcomputer. It can be used in a desktop workstation operation for word processing, database retrieval or any number of the other functions. It is essentially a high level tool kit which reportedly allows for simultaneous accessing of databases on CD-ROM or Winchester or an optical write-once disc.
11. ADONIS: This is a trial document delivery service that supplies 219 biomedical journals on CD-ROM on a weekly basis. The supply centers are in Europe, the United States of America, Mexico, Australia and Japan and are used to fulfill requests for individual articles received by the centers in the course of their normal activities. [Ref. 18]
12. Manuals on CD: Minicomputer companies like Hewlett Packard offer a CD-ROM version of their computer manuals, which would otherwise fill a small bookcase. Rather than search through manuals, the user can let the computer search for the answer. [Ref. 8:p. 1F]
13. "USSR SOURCE 21": A 30 Megabyte database which is part of a series produced by Alde Publishing. It contains Soviet designed software, the Communist Manifesto, gross economic indicators since 1960, space launches and payloads, information on weapons systems

since 1965, USSR world records, cartographic information, transcripts of Academy of Sciences meeting, KGB and Politburo charts and members since 1912, etc.

14. "Silversmith/GS": A retrieval software by Taunton Engineering designed to retrieve information from DOD documents containing codes for printing and formatting based on the proposed standard called SGML (Standard General Markup Language)<sup>5</sup>. Information can be retrieved on any full-text term or on one of the SGML tags.
15. "FYI 3000 Plus": A text indexing and retrieval software. It will index 65000 paragraphs of 1000 words each in a single filing system. It employs full Boolean logic searching and browsing by line or page. Average search speed is three seconds. The price is \$195. [Ref. 19]
16. Innovative Technology's "Crosslink" on CD-ROM: A database of over 6.6 million supply items in the federal catalog with related data. It is produced by Information Handling Systems (IHS). It contains technical and logistics supply data, such as Master Cross Reference list (MCRL), Management List-Consolidated (ML-C), Commercial and Government Guilty (CAGE) H4/H8, Dun and Bradstreet vender profile, and others. The government price of the 2-disc subscription is \$4,100. [Ref. 20]
17. "QwikCat and QwikTreve": Two retrieval software packages by MVC Corporation. QwikCat is designed for cataloged information and will also handle text, pictures, graphics and sound. Qwik Treve is geared toward business industry needs. [Ref. 20:p. 60]
18. "OS-DOS": Software package by Optical Storage Solutions, Inc., to allow any IBM-compatible microcomputer to communicate with an optical disk drive. Addresses one gigabyte of storage space as a single data area. Access time to any file on the disc is reportedly 500 milliseconds. [Ref. 21]

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<sup>5</sup>Better known as DOD-M (SGML). It is a document markup specification designed to facilitate the automated interchange and processing of electronic databases among government agencies and DOD suppliers. It is used to facilitate the retrieval of information from electronic databases of technical documents conforming to the specification labeled MIL-M-38784.



## 2. Software Trends

The future will be based on the particular desires of the user. Participating libraries appear to be sharing information more readily through this technology. Business appears to be expanding its use of laser discs. The February 1988 issue of CD-ROM magazine quoted Mr. McGlagan, Vice President of Lotus' Information Services Division, that Lotus reportedly plans "to be the leading producer of financial and business information on CD-ROM." Inroads are also being made in government and particularly in DOD to use laser technology in such areas as DOD construction.

This chapter discussed the complexity of laser technology along with some of its many uses. In Chapter III, laser technology and its uses in Navy Constuction will be investigated. Chapter V will investigate whether laser technology will be cost effective for the United States Government.

### III. LASER TECHNOLOGY IN CONSTRUCTION

This chapter discusses the standards necessary to develop and administer United States Government construction contracts. It describes where the government construction industry, specifically the Naval Facilities Engineering Command (NAVFAC), is presently in the use of laser technology. It also describes future uses of laser technology in government construction.

Construction projects are normally conducted using a set of plans and specifications. These documents are the basis for bidding on construction projects by prospective construction contractors prior to the awarding of a contract. Subsequent to an award, plans and specifications become the documents used by the chosen contractor to complete the construction project. The quality of these documents are critical for the delivery of a satisfactory product within budgeted funds. Poor quality could cause time delays, change orders, legal battles and an unsatisfactory product.

Successful execution of the plans, specifications and design requires a great deal of data not presented in these documents. This is most apparent when dealing with the specifications. A set of construction contract specifications contain numerous references to construction standards

which would be too voluminous to include directly in the specifications section of a contract. For example, a contract could include specifications, for placing concrete shown on the drawings in accordance with ACI 302. This is the standard published by the American Concrete Institute titled, "Guide to Concrete Floor and Slab Construction." The one sentence reference in the specifications takes the place of the desired method of placing the concrete. The specification itself may be several pages long. In addition, standards are valuable because they describe proven and acceptable construction and testing procedures.

There are dozens of nongovernment standards bodies (NGSB)<sup>1</sup> which publish volumes of standards for all aspects of construction. The more commonly referenced and nationally recognized bodies are listed in Figure 9. These are commonly referred to as industry standards.

The nongovernment societies sell their standards in book or microfiche form. The funds from their sale is used to support their work. Standards need to be periodically revised and new ones written. Within DOD Construction, there are additional military and federal specifications and standard drawings which are followed. Designers, contractors and contract administrators all need to have

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<sup>1</sup>Nongovernment Standards Body is defined here as scientific, technical, professional or other organization, society or association, not organized for profit which conducts professional standardizational activities.

<b>AASHTO</b>	American Association of State Highway and Transportation Officials
<b>AATCC</b>	American Association of Textile Chemists and Colorists (Included in ASTM Textiles Section)
<b>ACI</b>	American Concrete Institute
<b>AFBMA</b>	Anti-Friction Bearing Manufacturers Association
<b>A.G.A.</b>	American Gas Association
<b>AGMA</b>	American Gear Manufacturers Association
<b>AIA</b>	Aerospace Industries Association of America, Inc.
<b>A.I.A.</b>	The American Institute of Architects
<b>AIChE</b>	American Institute of Chemical Engineers
<b>AISC</b>	American Institute of Steel Construction, Inc.
<b>ANS</b>	American Nuclear Society
<b>ANSI</b>	American National Standards Institute
<b>API</b>	American Petroleum Institute
<b>AREA</b>	American Railway Engineering Association
<b>ARI</b>	Air-Conditioning and Refrigeration Institute
<b>ARINC</b>	Aeronautical Radio, Inc.
<b>ASA</b>	Acoustical Society of America
<b>ASAE</b>	American Society of Agricultural Engineers
<b>ASCE</b>	American Society of Civil Engineers
<b>ASHRAE</b>	American Society of Heating, Refrigerating and Air-Conditioning Engineers
<b>ASME</b>	American Society of Mechanical Engineers
<b>ASNT</b>	American Society for Nondestructive Testing
<b>ASQC</b>	American Society for Quality Control
<b>ASSE</b>	American Society of Sanitary Engineering
<b>ASTM</b>	American Society for Testing and Materials AATCC (American Association of Textile Chemists and Colorists)
<b>AWS</b>	American Welding Society, Inc.
<b>AWWA</b>	American Water Works Association
<b>CGA</b>	Compressed Gas Association, Inc.
<b>EIA</b>	Electronic Industries Association
<b>GPA</b>	Gas Processors Association
<b>IEEE</b>	Institute of Electrical and Electronics Engineers
<b>IES</b>	Illuminating Engineering Society
<b>IFI</b>	Industrial Fasteners Institute
<b>IPC</b>	The Institute for Interconnecting and Packaging Electronic Circuits
<b>ISA</b>	Instrument Society of America
<b>MSS</b>	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
<b>NACE</b>	National Association of Corrosion Engineers
<b>NEMA</b>	National Electrical Manufacturers Association
<b>NFPA</b>	National Fire Protection Association
<b>NFPA(A)</b>	National Fluid Power Association
<b>NSF</b>	National Sanitation Foundation
<b>PFI</b>	Pipe Fabrication Institute
<b>RTCA</b>	Radio Technical Commission for Aeronautics
<b>SAE</b>	Society of Automotive Engineers
<b>SEMI</b>	Semiconductor Equipment and Materials Institute, Inc.
<b>SMACNA</b>	Sheet Metal and Air Conditioning Contractors' National Association, Inc.
<b>SSPC</b>	Steel Structures Painting Council
<b>TAPPI</b>	
<b>UL</b>	Underwriters Laboratories Inc.

#### Combination Standards Services

DoD Adopted Industry Standards
Drafting Standards Service
Environmental Protection Agency Service
Federal Information Processing Standards Service
Historical Industry Standards Services

Figure 9. Nongovernment Standards Bodies

access to this vast amount of information. Rarely are all the required documents found in one place, accessible to all parties concerned. Therefore, retrieval involves extra time and effort, using resources that could be very likely used more productively.

The government could possibly avoid this inefficient use of resources by the use of laser technology. It has the ability to store large amounts of data on one easily accessible disc. The feasibility of using laser technology in the United States Government should be investigated to determine if the benefits are greater than the costs of adopting and using the new technology. A cost-benefit analysis and its results is presented in Chapter V. The status quo, with all of its inherent problems, should be one alternative to consider. Changing from the status quo will have associated costs and benefits. These need to be weighed and analysed before changes are instituted.

#### A. PRESENT STATUS OF CONSTRUCTION STANDARDS

##### 1. Department of Defense

DOD construction standards are primarily in paper and microfilm form. There is also a pilot program underway which uses the CD-ROM. This is explained in detail in this section.

Paper standards come in all shapes and sizes and from various sources. Rarely does any one office have all the currently listed publications on hand. The space and

cost requirements alone to acquire them would be prohibitive. Maintaining these standards periodic updates would also be a time consuming and prohibitively expensive project. There are paper libraries throughout DOD which house portions of these publications. For instance, within the Department of the Navy (DON), the Naval Facilities Engineering Command (NAVFAC) maintains extensive libraries of standards at its headquarters and six Engineering Field Divisions (EFD). NAVFAC is the construction agent for the Navy's \$3 billion worth of annual construction projects. However, NAVFAC's thousands of field offices, designers, and construction contractors cannot be as well stocked with standards as they ideally should be.

A prevalent media for standards libraries in DOD are microfiche and microfilm. These products usually contain standards by the nongovernment standards bodies such as the American National Standards Institute (ANSI), (ASTM), and (ASME). The microfiche/microfilm are normally purchased directly from the respective society in lieu of paper form or from an authorized intermediary such as the Information Handling Services Company (IHS).

As with the paperbound counterparts, these standards on microfiche and microfilm are costly to purchase and to maintain. Therefore, they are normally acquired only by the large central organizations such as NAVFAC or their EFDs. One of these EFDs, Northern Division, covers an area which

includes 24 states ranging from Colorado to Maine. Although the small field offices, the smaller Architect/Engineer (A/E) firms and construction contractors are tasked with producing and executing the plans and specifications these units cannot afford to maintain adequate libraries.

There are approximately 250,000 pages of federal and agency guide specifications, design manuals, illustrations and other related construction projects. [Ref. 22] These include about 4650 military and federal specifications. Within the NAVFAC community itself, there are over 3300 government and nongovernment standards used for construction programs (see Figure 10). These standards are written and updated by many agencies and are available in one or more of the three media mentioned above. There are two specific programs which seek to address this large library of data in an effort to simplify and improve access to it.

The first program is being undertaken by the office of the Secretary of Defense through guidelines outlined in two directives:

1. Office of Management and Budget (OMB) Circular A-119, titled, "Federal Participation in the Development and Use of Voluntary Standards."
2. DOD Directive 4120.3, titled, "Defense Standardization and Specification Program."

These documents were created to establish a policy for the federal government to begin using nongovernment standards in preference to military and federal documents whenever feasible and consistent with law and regulation. [Ref. 23]

<u>Type of Criteria</u>	<u>Quantity</u>
1. NAVFAC Construction Guide Specifications	308
2. Standard Construction Specifications Drawings	238
3. Design Manuals and NAVFAC Publications	109
4. Special Government Specifications and Standards	130
5. Military and Federal Specifications	574
6. Nongovernment Standards	<u>1970</u>
Total	<u>3329</u>

Source: Thomas L. Hinds Article for ASTM News, April 1988.

Figure 10. Types and Quantities of Criteria Documents used by NAVFAC for the Navy Construction Program

The present DOD policy is to participate in standard development, and to adopt and use nongovernment standards to the extent feasible, practical and economical. The adoption and use of acceptable nongovernment standards helps to ensure DOD has use of products and practices which are readily available in the commercial marketplace. Additionally, it minimizes the need to prepare and maintain military documents.

In keeping with the intent of the DOD policy, the Armed Services have taken steps to reduce the number of



military specifications. As a result, between 1980 and 1987, approximately 940 industry standards were adopted (see Figures 11 and 12). NAVFAC has assured successful adoption of nongovernment standards by participating in the voluntary standards writing organizations. These standards can then be influenced to consider the needs of the military. Nonetheless, the unique nature of some military construction projects necessitates the continued use of much of the remaining standards. The next section addresses the second program which concerns the accessibility issue.

a. General Description of the CCB program

DOD has had several pilot programs since the mid-1970's to make existing construction standards more accessible to governmental users. These programs have been combined into the NASA, NAVFAC and DOD-sponsored system which will be described below. The program is called "CCB" which stands for Construction Criteria Base. CCB is a construction criteria library on compact disc in ROM form. Its main working tool is "SPECSINTACT" or Specification Kept Intact. This is an automated system for developing construction project specifications.

The original SPECSINTACT system was developed by NASA for use by their construction specifiers and A/E contractors. The Army and Navy decided to modify the system for their use in 1986/87.

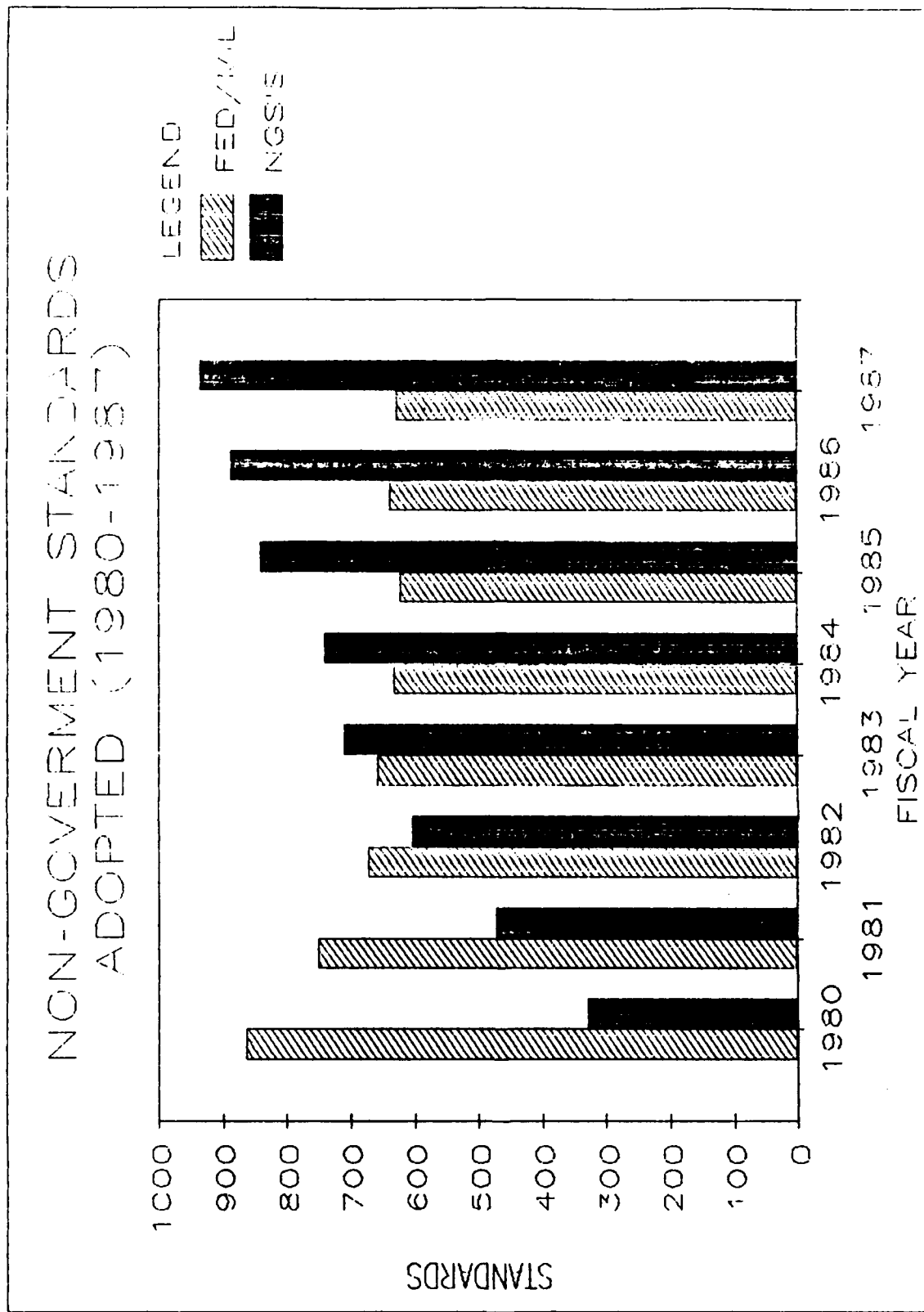


Figure 11. Nongovernment Standards Adopted (1980-1987)

Architectural Aluminum Manufacturers Assn. (AMMA)*	4
American Concrete Institute (ACI)*	23
American Institute of Timber Construction (AITC)	1
American National Standards Institute, Inc. (ANSI)*	69
American Petroleum Institute (API)	15
Air-Conditioning and Refrigeration Institute (ARI)	18
American Society for Testing and Materials (ASTM)*	588
American Wood-Preservers Assn./Bureau (AWPA/AWPB)*	15
American Welding Society, Inc. (AWS)*	17
American Water Works Assn., Inc. (AWWA)*	31
Builders' Hardware Manufacturers Assn., Inc. (BHMA)*	11
Cast Iron Soil Pipe Institute (CISP)	2
Construction Specifications Institute, Inc. (CSI)	2
Deep Foundations Institute (DFI)	2
Hardwood Plywood Manufacturers Assn. (HPMA)	1
Institute of Electrical and Electronics Engineers, Inc (IEEE)*	12
Manufacturers Standardization Society of the Valve and Fittings Industry (MSS)	12
National Electrical Manufacturers Assn. (NEMA)	17
National Fire Protection Assn., Inc. (NFPA)	7
National Sanitation Foundation (LSF)	4
Plumbing and Drainage Institute (PDI)	2
Steel Door Institute (SDI)*	5
Steel Structures Painting Council (SSPC)*	21
Underwriters Laboratories, Inc. (UL)*	60
<b>TOTAL</b>	<b>938</b>

\*Organizations where NAVFAC personnel has memberships.

Figure 12: Industry Standards Writing Organizations with Documents Adopted by NAVFAC

CCB originated as a NAVFAC and DOD-sponsored system for putting construction criteria on compact disc. It was developed by NIBS the (National Institute of Building Sciences), a government-created nonprofit organization whose purpose is to assist the construction industry. CCB is a quarterly updated disc distributed to subscribers with the purpose of providing an accessible, complete, affordable and uniform criteria base. DOD hopes the program will reduce confusion and legal problems.

CCB contains the following data bases:

1. NAVFAC guide specifications
2. Army Corps of Engineers guide specifications
3. NASA guide specifications
4. Veterans Administration (VA) guide specifications
5. 100 military specifications
6. NAVFAC design manuals
7. The SPECSINTACT program
8. Search and retrieval software ("Volkswriter 3" and "Superkey" are necessary and "Sidekick" is optional).

The above information takes up one-fifth of the total usable disc space of 250,000 pages. The first disc was issued in July 1987. The system is presently used by NASA, the Navy, the Army and private contractors. The Air Force has seen demonstrations of the system but has not yet actively participated in the program.

The steps in making a CCB disc are illustrated in Figures 13 and 14. Basically, the standards obtained

## HOW

Criteria enter CCB from many organizations in many forms

### CCB Data Management

- System Management
- Information Organization
- Advisory Committee
- Update coordination
- Reformatting
- Full text indexing
- System validation

Mass production of CD-ROM Discs

Available to end users through building community organizations

Discs useable on hundred of thousands of existing micro-computers -- providing instant access and advanced information handling

Faster, lower cost production of project specifications, reduced "learning curve"

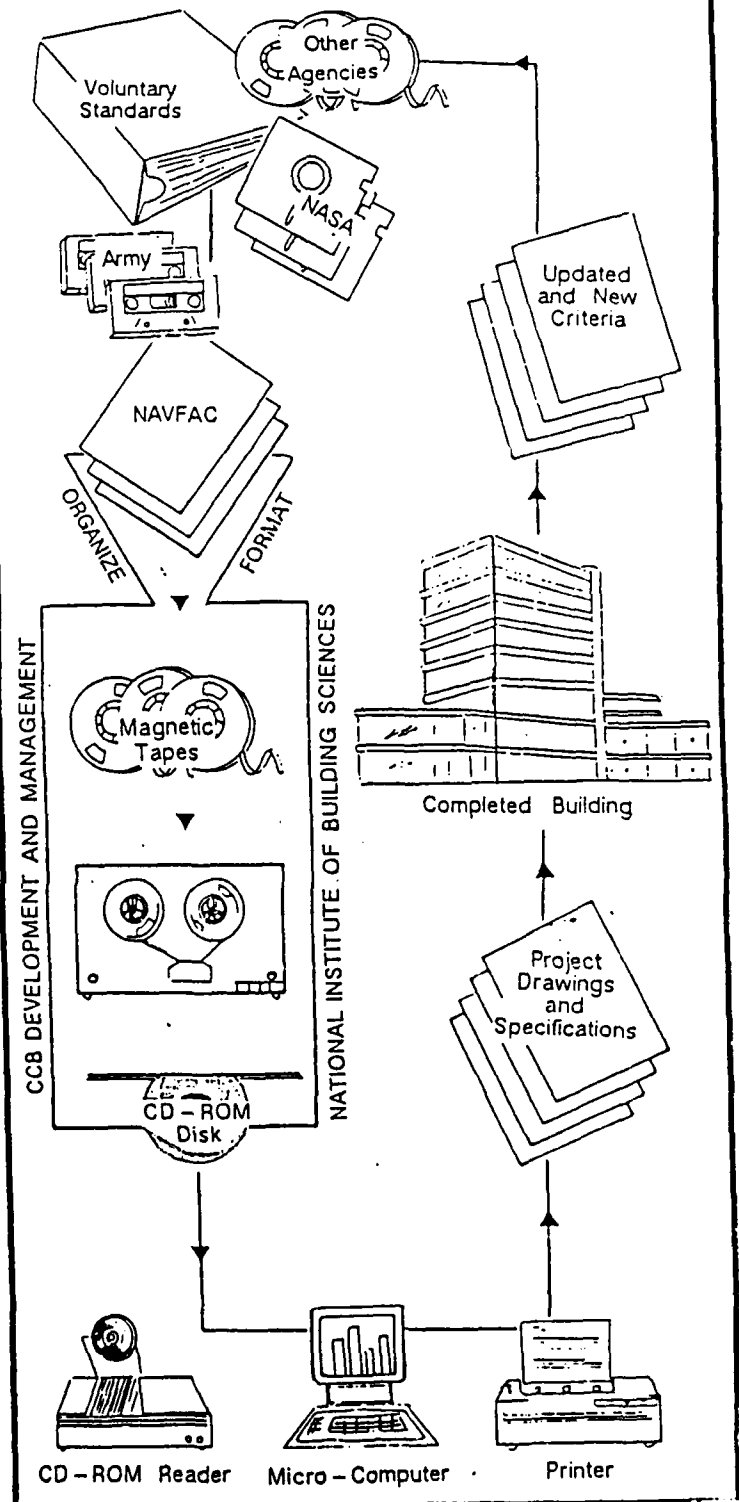
### Projected results:

- Eliminate error sources
- Fewer expensive change orders
- Greater design productivity
- Improved design quality
- Design Reviews facilitated
- Faster project completion
- Better construction quality

### Criteria Improvement:

- Better criteria coordination
- More input to criteria revision
- Piggy-back on other industry advances
- Better use of voluntary standards
- Fewer, more widely used criteria

## CCB WORKS



© Copyright 1987, National Institute of Building Sciences

Figure 13. How CCB Works

# CCB SYSTEM CHART

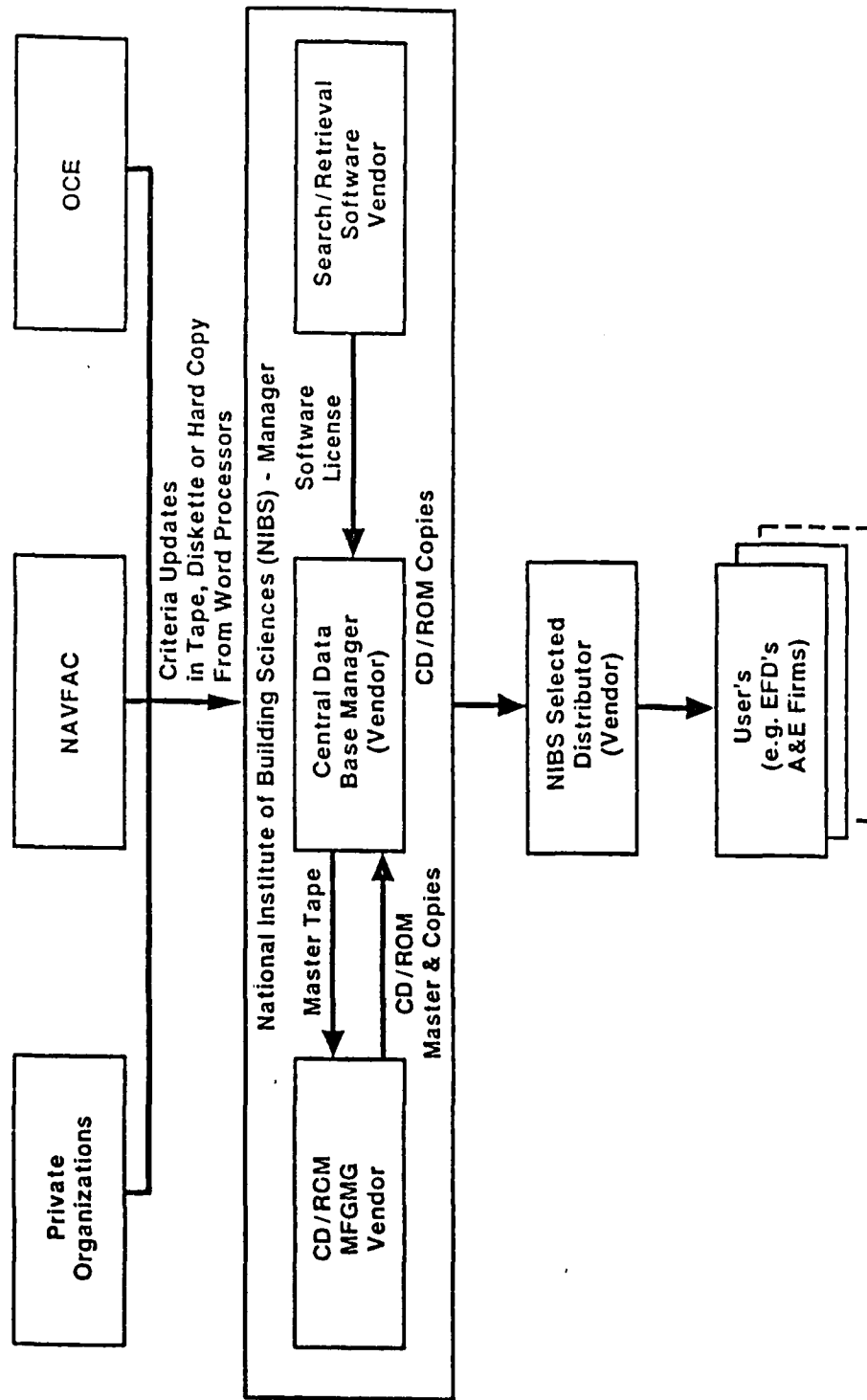


Figure 14. CCB System Chart

from various agencies are collected and go through steps similar to those described in Chapter II. They are placed on magnetic tapes, formatted and indexed. After the premastering is completed, the tapes are converted into a glass master at the mastering facility. Duplicate drives are then made from the master and distributed.

b. System requirements

In addition to the disc, subscribers need to invest in specific equipment (see Figure 15). These include hardware such as a CD-ROM reader and software to retrieve data from the disc and to manipulate it. The latter is mainly used to prepare complete contract specs containing all the specific standard sections desired for the particular job. A detailed description of the software follows:

SPECSINTACT system software--This system is available on the CCB compact disc or on floppy disk. It is a collection of executable program files, data files, batch files and other miscellaneous files necessary for system operation. SPECSINTACT acts like a shell which controls the operation of many programs and maintains the flow of data between various operations. It contains over 100 files and requires about 2 Mbytes of space.

CCB system software--CCB provides a user friendly interface when working with the CD. In addition to SPECSINTACT, CCB holds a search program, a retrieval program and translation software for translating from ASCII to one of ten word processing packages.

Volkswriter 3--is a commercially available word processing software package used by the SPECSINTACT system. SPECSINTACT is unable to use any other word processing package at this time. Volkswriter is used to edit specification text and to print documents. It is automatically set up for processing by SPECSINTACT. Currently there is a study to make SPECSINTACT more word

# RECOMMENDED EQUIPMENT CONFIGURATION

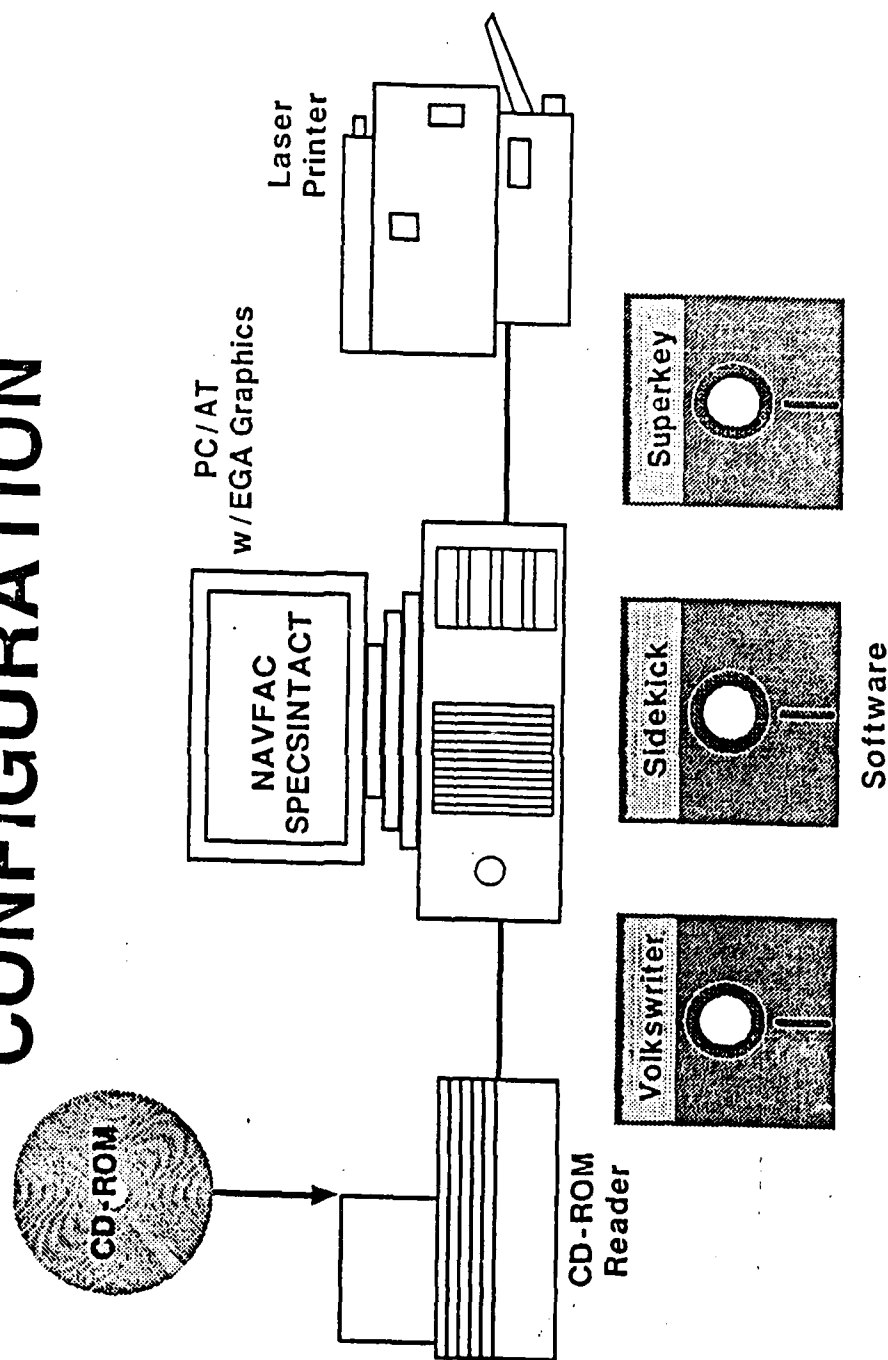


Figure 15. Recommended Equipment Configuration



processor independent so that other available word processing software may be used just as easily in the system.

Superkey--This is a commercial software package required to run SPECSINTACT. It provides macro<sup>2</sup> capability. Superkey is used by SPECSINTACT when editing a spec in Volkswriter, providing pre-defined macros for frequently entered words, commands, and keystrokes.

Sidekick--This is an optional software package. Its functions include notepad editor, calculator and phone directory. If loaded, the user can call up Sidekick within SPECSINTACT or another program without having to exit first.

### c. System Description

The three main features of the CCB system are as follows:

Full-text search--CCB provides a program called Fast-Find that is able to search any CCB data base for a word or group of words. It is able to find a word or a phrase in 5 seconds. It would take days to do the same search using a word processor due to the size of the data base.

Retrieval--CCB provides an on-screen listing of all the titles and numbers of the documents it contains. The user can then see the full text of the document on the screen, copy retrieval documents to floppy or hard disk or print them out.

Translation to word processors--The CCB program SoftScan is able to translate documents from the CCB data base in ASCII to any one of ten word processing formats.

The main features of the SPECSINTACT system are as follows:

CSI format--SPECSINTACT is preloaded with the 16 divisions of the generally accepted specification division titles. Within each division are sections each dealing with a specific topic. The sections are broken into three parts: General, Products and Execution. Within each part are subparts or paragraphs.

---

<sup>2</sup>Macros are short abbreviations which replace a series of keystrokes. Codes entered through macros are entered correctly and consistently each time.

Reference verification--This verifies whether the references in the specification text within a job have been included in either an article 1.2, or a section 002. Unmatched references are also identified. This is significantly faster than a visual cross reference check and greatly reduces the chance of error.

Test requirement report--This is a report generated from the print menu. All test and other requirements coded in the body of the text are included.

Submittal--Submittal are items the government requires the A/E firm or contractor to include in their bid packages. A list may be generated of all the submittal called out in the text.

Section reference verification--This ensures that all sections referenced in the job are included as part of the job.

Renumber paragraphs--This automatically rennumbers the paragraphs.

Page number by section--This feature gives the option of printing the Project Specification with either sequential numbers from beginning to end or with each section starting with page number one.

Table of contents--Automatic feature.

Automatic Note deletion.

On-line viewing of reference data--Provides the capability to look up a reference by its number (i.e., ANSI), and view the publication source and date.

Configuration and Installation--Automatic feature.

Multiple Specification Sources--Allows the inclusion of spec text from multiple files.

Job status information--Hours expended, date and time of receipt may be recorded.

Printing features. [Ref. 24]

## 2. Non-DOD

The non-DOD standards groups of concern are those identified in the Defense Standardization and Specification

Program described above and those listed in Figure 10. All of these organizations depend on the income received from the sale of their standards. Paper and microfiche are the predominant media used by them.

Many nongovernment standards bodies also sell copy rights to such intermediaries as Information Handling Services, Inc. These intermediaries in turn sell packages of standards to customers. Convenience and quickness of delivery make this company's product popular with subscribers. They even sell government standards packages back to different government agencies who find it a more convenient way to get the data!

Several NGSBs are in the process of working out problems of producing their standards in CD-ROM form. The process is ongoing and involves predominantly proprietary information. The initiative appears promising despite the lack of public information on the process. IHS is also negotiating with many of the NGSBs for rights to publish their standards in CD-ROM form. [Ref. 25]

## B. FUTURE APPLICATIONS

### 1. Department of Defense

One goal of the Defense Standardization and Specification Program is the continued increase in use of nongovernment standards in government construction projects.

The goals of the CCB group are to include more on the disc than presently exists (see Figure 16). The intent

# ENGINEERING CRITERIA SYSTEM

## CDROM SPACE ALLOCATIONS

<u>Applications</u>	<u>MEGA BYTES</u>
✓ NAVFAC Guide Specs	31
✓ COE Guide Specs	31
✓ NASA Guide Specs	16
✓ BUREC Guide Specs	31
✓ VA Guide Specs	27 (PARTIAL)
✓ Guide Spec Reference Matrix	2
✓ NAVFAC Design Manuals	36 (PARTIAL)
✓ COE Technical Manuals	54
✓ Air Force Manuals	18
✓ Mil/Fed Specs	90 (PARTIAL)
✓ GSA Specs	36
✓ DOE Specs	9
✓ Illustrations (NAVFAC & COE)	140
✓ NAVFAC CES-Estimating	10
✓ Utility programs	10
✓ TOTAL (1 CDROM - 550MB)	<hr/> 540 MB
✓ JANUARY 1988 STATUS	

Figure 16. Engineering Criteria System

is to add all remaining federal specifications and then add the nongovernment standards which are used on DOD construction projects.

Several problems are anticipated in this process. Figure 16 demonstrates that the disc would be nearly full before the anticipated addition of the nongovernment standards. The biggest storage capacity user by far appears to be drawings and other such images. They in turn are subject to the quality and indexing problems discussed in Chapter II. A second disc is a possibility but hardware and software problems would arise. Most customers presently have single CD-ROM readers. The issues of royalty costs and the acquiring of agreement from the several dozen societies could also have a negative impact.

## 2. Non-DOD

Both the NGSBs and their intermediaries desire to produce CD-ROMs but face some difficulties. Royalty issues and copyright protection are both problems. Some experts believe that no matter how well a program is encoded to protect unauthorized copying, someone will find a way of breaking through the code. Resolution of these problems remain problematic.

Chapter II discussed the hardware and software associated with laser technology. Chapter III discussed the CD-ROM system that NAVFAC is using to improve the development and administration of government construction

contracts. The cost of this system and its benefits are discussed in the fourth chapter.

#### IV. CONTRACT SPECIFICATION COMPARISON

This chapter describes the process presently used in preparing contract specifications within NAVFAC and its EFDs. Then, it describes how this process would be performed on CD-ROM using the new CCB system described in Chapter III. A comparison of these two systems will be done using a typical contract specification for a construction project. This will provide the reader with a better understanding of the specification preparation process. The comparison will identify the differences and highlight the benefits of the two systems.

##### A. PRESENT SYSTEM

###### 1. Staffing and Resources

The typical Engineering Field Division specification writing branch is staffed as follows:

1. six to ten engineers (GS-12 with an annual salary of \$30,000 each).
2. one or two secretaries.
3. one supervisor (GS-14 with annual salary of \$40,000).

The equipment available to the above staff include the following:

1. two or three WANG<sup>1</sup> word processing and telecommunication systems.
2. a microfilm library of nongovernment standards and government standards.
3. limited paper libraries of nongovernment and government standards.

## 2. Procedure for Contract Preparation

The following is a list of steps in the contract specification preparation process:

1. A project or project proposal is submitted by one of the Navy or Marine Corps activities that NAVFAC is responsible for to its respective EFD. The project is separated by discipline (i.e., Mechanical, Electrical, Architect) and assigned by the supervisor to the appropriate engineer. A project which will contain all of the 16 commonly used construction sections described in Chapter III will be put together by several engineers. Each engineer would prepare the sections that he/she has more experience with.
2. The engineer reviews the design (plans) of the project and any other pertinent documentation. This gives the engineer an understanding of the scope and depth of the project.
3. The engineer then develops a written outline of the construction steps that will be followed. This allows him/her to decide what standards will be applicable for that project. Both government and nongovernment standards are used throughout the project depending on the quality and type of work to be performed.
4. The engineer then physically gathers the information necessary to write the specifications. This is done in a number of ways. (1) They can obtain a copy of a similar project specification to use as a rough guide and for cutting and pasting together identical portions needed in the new project.; or, (2) The

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<sup>1</sup>The Wang is a system primarily used for word processing. It is also capable of communicating with other WANG stations using a telephone modem. This system has limited capabilities because it is not able to communicate with other DOD activities that use different computer or word processing systems.



engineer can find all applicable standards dealing with a particular portion of the construction and then cut and paste the package together. This entails searching in paper libraries and microfilm libraries for applicable standards and pulling those out. On the microfilm standards, he/ she will browse through the standards for the ones that might be used and copies those on paper in order to have them on hand at his/her desk.

5. The engineer then decides on the appropriate clauses to write for the specification and the appropriate standards to reference for each section.
6. Next, the actual writing of the draft copy of the specification package occurs. This entails a good deal of cut and paste work. Undesired references to standards or other sections are deleted. Desired cross references to other sections are written in. Submittal<sup>2</sup> and testing requirements and sequences of operations are added where applicable.
7. The rough draft is then given to the secretary to be typed on the WANG word processor.
8. After the typing is complete, the supervisor reviews the draft and returns it to the engineer(s) for needed revisions.
9. Changes are made by the engineer and the cycle of the secretary and supervisor is repeated until a final copy of the specifications is prepared.
10. There are several additional steps undertaken at this point. A submittal list is prepared and attached to the specification package. To do this the engineer must go through the entire specification package and list all the submittal that have been specified. Upon completion of the specification package the supervisor must review again to make sure that all standards and guide specifications referenced are truly in the specification package. The lack of cross references here could result in a need for change orders or legal fees down the road. The manual cross referencing and the list of submittal is a time consuming process but very effective. Upon completion

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<sup>2</sup>Submittal are requirements placed into the specifications for the construction contractor to provide samples, brochures or designs which indicate details of intended construction procedures.

of this process the specification package is then put with the design package and sent to the contract division for advertising and award.

### 3. A/E Work Review

If a project is contracted to a civilian A/E firm for design, then much of the above work is done by that A/E. The plans and specifications would normally both be prepared by the same A/E.

The guidelines for the project and other pertinent information needs to be passed on to the A/E firm by the government. Normally, a WANG system cannot be used because most A/Es use microcomputers that are unable to read the WANG language. In this case, the government standards are transferred to the A/E firm in paper form or on magnetic diskettes (such as floppy disks). Either way, the A/E has to convert the information received into the format they can use on their computer.

Within the A/E organization, the steps followed for specification package preparation are similar to the above with a minor exception. The A/E would use the microcomputer, instead of a WANG to do their word processing. Upon completion of the specification package by the A/E firm, EFD supervisor would review the package. This review along with the transfer and conversion of government information adds two to four weeks to an average contract.

## B. CD-ROM SYSTEM

### 1. Staffing and Resources

The staff picture with the CCB system is expected to remain the same as it is for the present system described above. If it is proven that fewer personnel are necessary with the CCB system then these personnel reductions would be accomplished through attrition. The equipment picture is expected to have the following additions:

1. six Zenith Z-248 microcomputers.
2. six EGA color monitors.
3. six surge protectors.
4. six modems.
5. four dot matrix or laser printers.
6. four Construction Criteria Base (CCB) CD-ROM discs.

The equipment and CCB package details and interconnections were described extensively in Chapter III and will not be repeated here. The addition of the CCB discs are expected to replace all other government standards held in the other storage media. They are also expected to replace much of the manual processes of standards retrievals and specification package preparation. The WANG system itself will not be replaced due to the fact it is a sunk cost and can still be used for other word processing needs.

### 2. Procedure for Contract Preparation

The initial steps of the work flow up to the writing of an outline of the project by the engineer(s) is the same

as those listed in the present system description (see Section 1.a to 1.c). The discussion here will start from that point.

1. The engineer loads the project on the microcomputer using the SPECSINTACT software which is built into the CCB. This automatically provides an outline format to the 16 construction sections.
2. The engineer gathers the necessary information for each section by executing a search of the CCB library using simple work or phrase command. All the standards dealing with wire fences, for instance, may be requested and retrieved within five seconds.
3. The engineer writes the specification package using the VOLKSWRITER word processing software in the CCB package. References can be retrieved and reviewed at the workstation using the CD-ROM.
4. CCB then provides the user with a variety of options which would otherwise be done manually. It automatically scans the package and identifies mismatches in cross references, an otherwise time consuming and painstaking manual operation. It automatically provides a listing of all required submittal. Other features were identified in the detailed presentation of CCB in Chapter III.
5. The package given to the supervisor for review is a finished product with fewer human errors, such as missing cross references or incomplete submittal lists.

The primary difference between the present and proposed system at the design phase lie in the research and writing of the specifications. The main advantage of the CD-ROM system is that it allows the engineer to retrieve needed standards and to compose the text of the specifications at the computer workstation. Research time is decreased because standards are obtained in seconds from the CCB library as opposed to minutes or hours from various

paper and microfilm libraries. Additionally, the cut and paste type of specification writing is replaced by the more flexible word processing system. Depending on the particular set-up in the office, the secretary's typing of a draft copy may be eliminated.

The CCB system is an efficiency tool. It does not replace the engineering judgement needed to choose the proper standards associated with the assigned project. The system therefore results in cost savings at the specification writing phase and not in the judgement phase. There is not significant cost savings from the improved quality of the contents specification package. This is because the CCB can catch editing errors but not judgement errors. The vast majority of claims, legal court cases, in the specifications arena result from contract interpretation differences between the contractor and the government. These are basically due to the interpretation of the intent of the specific specifications as opposed to a missing or misplaced reference to a standard. [Ref. 26]

The manual mode of quality assurance now used in specification writing is very accurate and effective, but very time consuming. The cost and benefits of the CCB system are described and analyzed in Chapter V.

## V. ANALYSIS OF CD-ROM FOR STANDARDS IN DOD

Chapter III described the Construction Criteria Base (CCB) project undertaken in DOD and spearheaded by NAVFAC. Chapter IV described the process used to write a contract specification under the present system and then with CCB system installed. This chapter will analyze the economic justification of the CCB system.

The status of the CD-ROM project is detailed in Figure 16. It shows the CD-ROM disc for the CCB project as being 20 percent full. It also shows the projected additions of government documents. The scenario which is addressed in this chapter is the CD-ROM with all the government standards and associated images included. This alternative will then be compared with media other than CD-ROM used for storage of standards.

The material in this chapter is presented in the following manner:

1. An overview of the analysis procedure and the use of NAVFAC as a test platform is discussed.
2. A Cost Benefit Analysis (CBA) is detailed and includes a scenario definition, and quantifiable costs and benefits.
3. The Decision Making Models (DMM) presented which will include the results of the CBA plus a listing of qualitative and quantitative factors.

## A. OVERVIEW

It is necessary for the authors to identify the assumptions and parameters they will use in approaching this analysis. Once these are identified, the reader can better judge the credence to be given to the assessment.

Will CD-ROM improve the engineers' productivity? Will CD-ROM improve the quality of contracts and reduce the cost of their administration? Will CD-ROM save specification preparation time? Do the benefits of CD-ROM outweigh the costs? In answering these questions the chosen test platform is the DOD/NASA sponsored CCB program described in Chapters III and IV.

NAVFAC was chosen as the testing base because of its dynamic involvement in the CD-ROM project. The Director of Engineering and Design Criteria Management is actively engaged in overseeing the development and use of the CCB disc. Funds coming in from different sources, such as NASA and the Army, for the CCB project are sent through that office for coordination purposes. Engineering Management Concepts (EMC) is a consulting firm, based in Washington, D.C., used to develop economical methods of adding new material to the CD-ROM. NIBS, on the other hand, handles the day-to-day mechanics of preparing the military standards for the mastering process. This is an ongoing process due to the addition of new material and revisions to existing data.

1. How the CD-ROM will be Used in NAVFAC

The main objective of the Naval Facilities Engineering Command (NAVFAC) in peacetime is to build and maintain the Navy and Marine Corps shore facilities throughout the world. NAVFAC awards over three billion dollars worth of construction contracts per year to meet this objective. NAVFAC utilizes a decentralized mode of operation. This involves personnel at NAVFAC Headquarters, Engineering Field Divisions (EFDs), Officer-in-Charge of Construction and Resident Officer-in-Charge of Construction (OICC/ROICC) offices. Also included are the Construction Battalion Centers (CBCs), Public Works Centers (PWCs), and Public Works Departments (PWDs). The PWDs are located at numerous Navy shore activities and are part of each specific shore activity's chain of command.

Each of the six EFDs and Headquarters maintain a Design Division which is responsible for the design of Navy and Marine Corps shore facilities throughout the world. While 84 percent, or 2.5 billion dollars worth, of the design is contracted out to nongovernment architect/engineering (A/E) firms, the remaining design projects are too small to contract out within the statutory six percent fee limitation<sup>1</sup>. In addition, a small residual in-house

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<sup>1</sup>Design costs of construction contracts are congressionally mandated to a six percent limit of the project cost. This makes it prohibitive to contract out the design of smaller projects. The resulting dollar limitation may be insufficient of pay for the A/E costs.



design effort is essential at each EFD to maintain staff professional expertise.

Design manuals and guide specifications are produced by the EFDs for NAVFAC. Specific project specifications are produced by the offices listed above for their individual contracts. The number of contracts prepared and awarded yearly, while dependent on the budgetary constraints developed by Congress during the fiscal year, is proportional to the size of the design division. For example, an EFD with 12 engineers has twice as many contracts as a PWD with six engineers. Information for this analysis was obtained primarily from NAVFAC headquarters and Western Division (WESTDIV), one of the six EFDs.

In addition to in-house use, NAVFAC requires the A/E firms and construction contractors to abide by the design criteria it provides. The A/E firm is required to follow the same guidelines for writing specifications as would be followed by a NAVFAC engineer. The procedures and parameters necessary to complete a project are provided by NAVFAC or its EFD upon award of the design contract. NAVFAC presently uses WANG word processing for generation of criteria and project specifications. The inability of the WANG to communicate with other computer systems was described in Chapter Four. The A/E firms, the Army Corps of Engineers and other Federal Agencies use IBM or IBM compatible personal computers that are not WANG compatible.

Therefore, the criteria must be reduced to a printed hard copy form, such as paper, for information exchange to occur. This creates a costly interface when coordinating project specification writing efforts with companies and agencies outside the NAVFAC community.

The CCB concept has been introduced for use throughout DOD. The IBM, or IBM compatible, personal computer would be the common hardware used in this system. The CD-ROM disc would be used as the common data base and floppy disks would be used as the common work disks. This would give DOD a completely compatible system for exchanging information between the various organizations.

#### B. COST BENEFIT ANALYSIS (CBA)

##### 1. Purpose of a CBA

A cost benefit analysis attempts to identify all significant effects a proposed project will have on the public. The valuation of the effects of the project is from the viewpoint of the affected individuals. The project effects are either costs or benefits, depending on the assessment of the affected persons. The purpose of a CBA is to assure that the diversion of private resources through taxes, for a government project, will yield at least as high a benefit as if the resources were expended by the individuals to enhance their own welfare. This cost benefit analysis attempts to do the above using NAVFAC, its six

EFDs, six PWCs, CESO, NCEL, CBC and NEESA as the basis for analysis (see Figure 21).

## 2. Collect Data

This section describes the data collection process used in this thesis. The CCB project is at the stage presently where a set of CD-ROMs has been produced and distributed to a limited population of subscribers. Each quarterly update adds standards and modifies those standards already on the disc. The Naval Facilities Engineering Command (NAVFAC) is in the process of training those subscribers who have the equipment on board. The authors were therefore able to use several sources for information.

The Engineering and Design Criteria Management Division of NAVFAC headquarters was used extensively for data collection on the present and future status of the program. The authors visited that Division in February 1988 and interviewed the director, Mr. Tom Rutherford. [Ref. 22] Mr. Rutherford referred the authors to individuals in other organizations for further data collection. Historical reports written during the initial design phase of the project were also utilized.<sup>2</sup> NAVFAC headquarters provided the essential information regarding the costs and expected benefits from the headquarters point of view. The next

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<sup>2</sup>An example of reports used is the NAVFAC code 04A memo 04M4B, 5236.11A dated 3 November 1986. That memo describes the intended use of the CCB project, identifies research money expended and expected to be spent and it identifies expected costs and benefits of the project.

source of data was obtained from the Engineering Field Divisions (EFDs). The specifications and design criteria branch at WESTDIV was used primarily because of its proximity to the Naval Postgraduate School. Mr. George Rauch and Mr. Gary Munekawa of WESTDIV were interviewed on several occasions. They provided information on the actual costs of equipment purchased, and the expected method of use and benefits of the CCB system. Their office prepares specification packages, reviews A/E designs, and updates the guide specifications allocated to them. Their office provided a better understanding of the application method and benefits involved with the CCB system. The initial phases of transition from the existing mode of operation to the CCB system was observed at WESTDIV by the authors beginning with the initial training session in March 1988.

Other EFDs were also used as sources of information. Northern Division Naval Facilities Engineering Command (NORTHDIV) was contacted regarding frequency, type and costs of legal cases related to specifications problems. NORTHDIV was used because the authors were familiar with the personnel there.

Construction contract administrators in Philadelphia were contacted. They were queried on specification related problems and on the usefulness of the CCB package at their level. Mr. Gerald Klein of the Resident Officer in Charge of Construction (ROICC) in Philadelphia was the primary

source of information with regard to contract administration.

The method of establishing the figures used in the cost/benefit analysis started with review of reports and interviews at the headquarters. Additional information and cross verification was done at the EFD level where specifications are prepared. The field level ROICC office was then consulted for information from the next level of specification user, the contract administrator. Finally, the legal counsel at the EFD was consulted for information on the specifications in cases where disputes arise between the contractor and the government.

The data presented in the quantitative analysis below are actual expenditures that have been incurred by NAVFAC for DOD. The costs and benefits associated with the nongovernment A/Es or any other civilian bodies are considered to be beyond the scope of this analysis.

The constraints on the project must be included in the analysis. These can be categorized as budgetary, legal, technological, environmental, and institutional. Some points on each constraint follow.

a. Budgetary

The DOD organization, in general, is subject to budget cuts resulting from Gramm-Rudman as well as limitations imposed by the Congressional budgetary process. Gramm-Rudman imposes automatic budget cuts if the annual

<u>ACTIVITIES</u>	<u># OF EACH ACTIVITY</u>	<u># OF Specification Engineers</u>
Headquarters	1	12
Engineering Field Division (EFD)	6	66
Officer in Charge of Construction (OICC)	50	50
Public Works Center (PWC)	6	12
Civil Engineering (CESO)	1	10
Naval Civil Engineering Lab (NCEL)	1	1
Construction Battalion Center (CBC)	3	3
Navy Energy and Environmental Support Activity (NEESA)	1	2
Totals	77	156

Source: NAVFACENGCOM code 011.

Figure 21. Activities Using CCB CD-ROM

budgetary process fails to reduce the deficit by a prescribed amount. The intent of the act is to eliminate the deficit by 1992. DOD is a major target of these automatic reductions. Congress can also limit the DOD budget through its annual appropriations acts. Both of the above actions can place indirect constraints on the CCB

budget. This is because overall DOD budget cuts would reduce funds available for projects not considered front line essential.

It is natural that the sources for the development and introduction of new construction or engineering techniques come from sources such as NAVFAC, Army Corps of Engineers (COE) and other DOD organizations involved in construction. These organizations fund research and development because they anticipate future benefits from those investments. The CCB project must be weighed by these DOD agencies with respect to other uses of their money. Funds provided for CCB by these agencies is therefore subject to CCB's relative importance to each agency.

b. Legal

No legal constraints are anticipated in the production of a CD-ROM with government standards.

c. Technological

This is a rapidly changing constraint. The upper limit, for instance, on the 4.72 inch CD-ROM storage capacity is 600 Mbyte. This will likely change through technological advances such as double sided discs as opposed to the single sided ones used now. Readers will have to accommodate new changes and that will entail purchase of new equipment. This also affects the analysis if monetary expenditures are required. For this analysis, the present state of the art described in Chapter III and presented in

Figure 15 will be assumed to be a given. Consequently the CBA will use only a five year horizon. It is unlikely that technology and equipment purchases, made during this study projection period, will change so dramatically as to make purchases from one year to the next obsolete.

d. Environmental

Realities existing in the market are important considerations. One of these is competition by commercial sources. The disc produced through NIBS can be produced by commercial vendors if they find it profitable to do so.

e. Institutional

There are inherent institutional barriers to the changes proposed by the use of CD-ROM. For example, the Air Force is not yet convinced of the benefits to them from the use of the CCB package. Formatting and indexing problems will surface when the standards of different Services are incorporated onto one disc. It is assumed that institutional differences will not make the premises of this study unusable during the period under consideration.

The analysis in this chapter uses 1988 constant prices and a ten percent discount rate for a time horizon of five years.

The rationale for using a ten percent discount rate is as follows. Experience shows that cost/benefit results can be quite sensitive to the discount rate chosen for the analysis. [Ref. 27:p. 128] There are arguments for



a lower rate as well as a higher one. Private or corporate investors, for instance, follow a formula which includes considerations for the government borrowing rate plus a risk premium times a tax rate factor. This can yield required rates of return much higher than ten percent. Finally, the Office of Management and Budget (1972) Circular No. A-94 sets a ten percent rate, which represents an estimate of the average rate of return on private investment, before taxes and after inflation.

The time frame chosen is five years based on the rate of change occurring in laser technology. It would be difficult to project beyond that period with any certainty.

#### 4. Quantitative Analysis

An important first step of a cost-benefit analysis is the identification of all the relevant costs and benefits. Second only to this is the quantification of such costs and benefits. [Ref. 28:p.43] Realizing the subjectivity in identifying and quantifying some of the benefits and costs, the authors have made an effort to substantiate the basis for their assessments.

Costs and benefits of the CCB system of specification writing described in Chapter IV can be categorized as direct or indirect. It is noted here that the bulk of the direct costs have already been expended. Research and development has been undertaken and continues

presently. Much of the equipment identified in the CBA has been purchased. Wherever possible, actual costs of such incurred expenses have been used in the qualitative portion of the CBA. A listing of costs and benefits follows below.

The direct costs include:

1. Research and development.
2. Hardware and Software acquisition.
3. CD-ROM publication.
4. Maintenance and enhancement (a recurring cost).
5. Training costs.

Indirect costs include:

1. Additional effort needed to coordinate work under the old system and the new.
2. Learning curve by employees.
3. Loss of time and employment of those unable or unwilling to change.

Direct benefits include:

1. Reduced research time for retrieval of standards.
2. Increased efficiency in preparing contract specification packages.
3. Reduced costs of providing standards to A/Es.
4. Reduced supervisors review time due to reduced number of errors in contract specifications such as inclusion of erroneous cross references.

Indirect benefits include:

1. Improved quality of specification packages.
2. Reduced conflict over contract terms and determination of liability (i.e., bidders should benefit, not just the government).

3. Reduced change order costs due to reduced errors in specifications.
4. Increased efficiency in contract execution due to fewer errors and change orders.

The indirect benefits are more appropriately categorized under the qualitative analysis portion of this chapter. They are included here for completeness. Additionally, identification of dollar values to those items would be extremely subjective. They should therefore be more appropriately assessed during the decision-making process.

The analysis of costs and benefits of the CCB system below were obtained from sources at NAVFAC headquarters and three EFD's. The three EFD's are Western Division (WESTDIV), Northern Division, and Southern Division. The actual money cost for research and equipment already purchased are used when appropriate. For example, WESTDIV has already purchased the recommended hardware. The costs used below correspond to WESTDIV's equipment acquisition costs.

a. Costs

(1) Research and Development. Research and development includes the cost for developing a CCB package that contains all the government documents and images listed in Figure 16. The first three item costs have already been expended. The work by EMC is ongoing presently. The associated cost estimates are obtained from NAVFAC.

Evaluation by NIBS	\$10,000
SPECSINTACT development by NASA	\$90,000
Criteria graphic development by NCEL	\$65,000
Indexing and formatting research (EMC)	<u>\$80,000</u>
Total	\$245,000

(2) Hardware and Software Acquisition<sup>3</sup> A description of hardware for the CCB system and how it is configured was presented in Chapter III and Figure 15. It is reviewed here for clarity purposes. The typical CCB system will consist of one IBM, or IBM compatible, microcomputer with a 20 Mbyte hard disk, one EGA color monitor, one Dot Matrix or laser printer, one CD-ROM Reader, one modem, and one surge protector. The software needed to run the CCB system is Volkswriter 3, Superkey and Sidekick.

Investigation of a newly installed CCB system at WESTDIV included six working microcomputers and CD-ROM terminals for approximately ten engineers. The limited amount of exposure during the present training phase indicates that this is a proper ratio for that office's workload. If necessary, WESTDIV plans to expand to a one engineer per workstation ratio after the training period. This analysis is therefore based on a one-to-one ratio.

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<sup>3</sup>The prices reflect quantities of 156 of each item which is the number of possible users in the NAVFAC community. It is assumed that 25% of facilities already own this equipment for other purposes and do not need to supplement their inventory. Therefore 75% of the microcomputer subtotal is used as the cost.

The costs presented below are for the equipment necessary to set up and operate the CCB system. The first of the two lists below is for equipment that NAVFAC and some of the EFDs have already purchased. This equipment was purchased for uses other than CCB but can be used for the CCB system. Accordingly, a portion of those costs are excluded as discussed in Footnote 3. The second list consists of equipment indigenous to the CCB system alone. The costs on both lists were obtained from NAVFAC headquarters and the EFDs. The actual prices for equipment purchased are used primarily.

Microcomputer and related items:

Computers (Zenith 7-248/20MB/1MB RAM)	\$249,600
EGA Color monitor high resolution	40,560
Surge protector	3,120
Modem, 2400/1200/300	24,960
Dot matrix printer	101,400
MS-DOS 3.0 and other essentials	<u>21,840</u>

Subtotal	\$441,480
75% of Subtotal	\$331,110

Extra 20 Mbyte hard disk (\$300/unit)	\$46,800
Reader (\$600/unit)	
CD-ROM interface board (\$225/unit)	35,100
Laser printer (\$1700/unit)	132,600
Volkswriter 3 (\$180/unit)	28,080
Superkey (\$95/unit)	14,820
Sidekick (optionally at \$60/unit)	<u>9,360</u>

Subtotal	<u>\$266,760</u>
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Total	\$597,870
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(3) CD-ROM Publication. CD-ROM publication for the first group of discs will only entail premastering and mastering since data collection is already done.

Total

\$10,000

(4) Maintenance and Enhancement. Maintenance and enhancement is based on quarterly updates over a five year period. The update costs are provided by NAVFAC headquarters. They include all the update costs involved with producing the quarterly CD-ROM discs. These costs are in turn passed on to the users via the \$550 annual subscription price. The subscription costs are therefore not included here to prevent double counting.

Data gathering (\$11,450 each)	\$229,000
Premastering and mastering (\$10000 each)	<u>200,000</u>

Total

\$429,000

(5) Training Costs. Training costs are divided into three categories. The first is the initial training of all 156 users. NAVFAC uses two trainers based in Port Hueneme, California who are scheduled for approximately 12 trips to the various user locations between December 1987 and May 1988. The cost figure is an estimate of their salaries, travel, et cetera during these initial training periods. The second cost figure shown represents the authors' estimate of the amount of time required by all users to bring themselves up to a comfortable working level. Once an individual is trained, additional training is not anticipated in the future. The third cost figure represents the cost necessary to train new engineers. A five percent turnover rate for engineers is assumed. These new employees must be trained individually.

The basis of the cost figures below is information gathered by the authors during various interviews and site visits primarily at the EFD.

Initial training	\$52,000
Individual training (80hrs x 156 x Wage Rate)	195,000
New employee training (80hrs x 7 x Wage Rate x 4yrs)	<u>35,000</u>
Total	\$282,000

Annual vs. one time cost breakdown:

One time first year costs (\$52,000 + \$195,000)	\$247,000
Recurring annual costs (Years 2 Through 5)	8,750

The undiscounted total of the five cost components is \$1,563,870.

The discounting of the cost over a five year period is shown below. Note that the \$247,000 of training costs occurs during the first year, while the \$8,750 is an annual cost during the subsequent four years. Also, the \$429,000 of maintenance costs must be spread over five years. The development and equipment purchases are also one time outlays during the first year.

Year	Amount	Discount Factor	Discounted Amount
0	\$1,185,670	1.000	\$ 1,185,670
1	94,550	.954	90,200
2	94,550	.876	82,825
3	94,550	.788	74,505
4	94,550	.717	67,790
Totals: \$1,563,870			\$ 1,500,990

b. Benefits

These benefits are calculated for a one year period for a steady state year following the assumed initial learning year.

(1) Research Time. Research time is reduced as a result of the software package that allows five second keyboard commanded retrieval of standards as opposed to searching in a book or on microfilm. The assumption is a government workforce of 156 engineers throughout the chosen agency would have need of retrieving standards for various reasons. The total number of retrievals per year would be 3700 per Engineer. This estimate was provided by WESTDIV and includes the retrieval of standards from libraries by engineers for all reasons. The Engineer may need to look up a standard, for instance, to answer a question raised by a telephone inquiry. The advantage of the CD over the other two forms of storage is estimated at 30 seconds per retrieval. A GS-12 Engineer's salary working for NAVFAC is \$30,000 per year.

Total Savings: \$74,880



(2) Project Time Savings. Project time savings is due to the accessibility of all needed information at one location workstation and at the touch of the keyboard. The time savings are a direct result of increased efficiency in the mechanics of putting together a specification package. The engineer retrieves standards directly from the disc library as opposed to walking over to paper libraries throughout the office. He puts together a complete package with automatic paragraph numbering, coversheet, etc.

Information obtained from the EFDs also indicates that on the average, an engineer at an EFD will work on about four in-house projects and review about 20 A/E designed projects per year. In addition, the 300 or so NAVFAC guide specifications are parceled out to the six EFDs for annual review and update. The engineers can use the CCB system to facilitate the mechanics of preparing the projects. The system does not assist the engineers in making better judgmental decisions.

	Existing	Proposed	Savings
In-house projects (4 projects x 156 engineers= 624/year)	\$1,340,625	1,072,500	268,125
Review of A/E projects (20 projects x 156 engineers= 3120/year)	1,950,000	1,560,000	390,000
Guide Specification Review (2 projects x 156 engineers = 312/year)	390,000	312,000	78,000
Cost of supervisor Reviews (4056 project x \$25/hr.x #hrs)	507,000	405,600	101,400

Total Savings \$837,525

(3) Reduced A/E Expenses. A/E's who bid on government contracts have an IBM, or IBM compatible, microcomputer and not a WANG system. The process used for an A/E to convert from NAVFAC's WANG format to a format compatible with their system is described below. Once the A/E is awarded the contract for design of a government project the A/E requests from the government (the EFD that is in charge of the project) all the required standards necessary to write the specifications. The A/E usually gives the EFD four floppy disks (an average number needed per project) where this information is loaded on from the WANG and returned to the A/E. The A/E then loads this information into a program such as "Word Doctor" and converts that information to an IBM compatible format. This loading and converting takes approximately 15 man hours per project at a cost of \$30.00 per hour. This currently required conversion of construction criteria from Wang format to the individual A/E's format will no longer be necessary. The A/E's will have a system that is compatible with NAFAC's CCB system. A/E fees will therefore be reduced commensurately. The comparison below uses four floppy disks. This is the present number of disks for standards data per project provided by the government to the A/Es. The comparison below uses 3120 as the average number of projects awarded to the A/Es annually. [Ref. 22] Mailing

costs are obviously reduced as well. The figures presented below are obtained from NAVFAC headquarters.

	Existing	Proposed	Savings
Cost of A/E disk(c) conversion (3120 A/Es x 15 hours x \$30/hour)	\$1,400,000	\$500,000	900,000
Cost of distribution (\$1/disk)	12,500	4,000	8,500

Total Savings \$908,500  
Total Yearly Benefits \$ 1,745,525

(4) Indirect Benefits. Indirect benefits are due to better communication between the government and the contractors. The authors believe that better quality specifications with fewer errors will result in an overall reduction in contract prices. Also, time that the A/E's engineers do not use in converting from WANG to IBM format cannot be used by the A/E in other productive areas. The authors feel that savings from these indirect benefits for both the government and the A/Es will amount to 1/4 of 1% of the total annual contract award amount. The calculation representing the dollar amount of those indirect benefits is shown below.

Savings:  $\$3,000,000,000 \times .25\% = \$7,500,000$

It is noted that this number is not sufficiently substantiated to be included in the totals below.

Assuming that no benefits are realized during the first year due to training and learning

differences the five year period discounted at 10% gives the following results:

Year	Amount	Discount Factor	Discounted Amount
0	0	1.000	0 *
1	1,745,525	0.954	1,665,230
2	1,745,525	0.867	1,513,370
3	1,745,525	0.788	1,375,470
4	1,745,525	0.717	1,251,541

Totals \$ 6,982,100

\$ 5,805,611

\*This is a very conservative estimate. However, it is not completely off due to the personal observations of the authors in the field. It takes a lot of effort with trial and error use of a sample contract, to gain sufficient confidence in using the CCB package. Additionally, it is believed that after the initial year of learning, a steady state should be reached.

Benefit to Cost Ratio=  $\frac{5,805,611}{1,500.990} = 3.87$

Payback Period: 1.7 years

#### 5. Qualitative Analysis

Many of the qualitative aspects of the CD-ROM in comparison to the present situation have been included in the listings in the previous section. They are much more judgemental than the quantitative benefits. Accordingly, the dollar values assigned will vary greatly from user to user. An example is the benefits of reduced legal costs. Two discussions using a non-conservative and a conservative approach follow in that order.

##### a. Non-conservative Approach

The preceding chapter presented the argument that the primary cost savings were associated with mechanical efficiency. At least 95% of the errors are found

during the editing phase of the present system, but it is a labor intensive process. Those contracts with errors that are not discovered represent perhaps five percent of the total contracts. [Ref. 38] The legal disputes arising from the specifications are primarily due to contract interpretation differences between the contractor and the government. Nonetheless, when editing errors occur presently, they result in change orders, claims or legal cases, usually in that order. Most situations (90%) are resolved at the change order level. Another eight percent are resolved at the claims level and the remaining may go to adjudication.

Change orders may be resolved at no additional cost to the government or they may cost several thousand dollars depending on the additional work needed. Claims against the government are handled through the Contracting Officer's chain of command. The contractor brings his disagreement with the contract administrator up to the level of the contracting officer (Commander, NAVFAC). This is usually a more costly arrangement than change orders because interest and other additional expenses are added in. Additionally, more in-house people are involved and the costs associated with their time and effort are involved.

Finally, cases that are adjudicated in court in favor of the contractor have a very high total cost

associated with them [Ref. 39] An average case may include the following:

1. three weeks of attorney time with a journeyman counsel at the GS-12 to GS-13 level making \$33,000 to \$45,000 per year,
2. legal costs of claimant,
3. judgment costs which would include costs of the additional work (see change order above) and related costs, such as delays,
4. prehearing, hearing and posthearing costs including costs of witnesses during discovery (prehearing) and trial phases.

b. Conservative Approach

The conservative side of the picture presented by the three types of offices consulted results in a negligible legal cost savings. The background for that conclusion is presented below. It is emphasized that the material presented below is that put forth by conservative viewers of the system as it is presently and will be in the future.

The specification writing branch in the EFD could take the position that problems with the specifications fall under the judgemental category. The engineer needs to use proper judgement in deciding which of the standards are proper for the job at hand. These decisions are not helped by a system such as the CCB according to proponents of this position. Those in the ROICC offices and at the EFD legal counsel offices with similar views support this position by citing the nature of

similar views support this position by citing the nature of change orders or legal cases that are encountered.

#### 6. Decision Criteria

The decision maker has a number of things to consider. The authors have chosen the NAVFAC System Decision Paper (ASDP) as a guide for use in the decision making process (see Appendix A).

A summary of what can be inferred from the above detailed cost/benefit analysis is presented below.

For the purpose of quantitative analysis, a five year time frame was chosen starting with the initial training and implementation year. The research and development and equipment acquisition costs given also have been included on the system cost side. Conversely, on the benefits side, only known or certain benefits have been included. Additionally, the authors have discounted any possible benefits for the first year. The inference should be that the CBA presented in this chapter is a conservative one. Nonetheless, the payback period is less than two years. That indicates that the system pays for itself during the first year of use where benefits are added into the analysis.

The qualitative portion of the analysis above includes, among other things, the bulk of the indirect

benefits. Qualitative considerations are particularly subject to judgemental biases. The example of the possible reduced legal costs has been presented from two perspectives: nonconservative and conservative. That presentation highlights the fact that qualitative analysis is subject to varied interpretations.

The authors also present the quantitative total of all indirect benefits as 1/4 of one percent of the total contract dollars expended per year. The dollar amount associated with those benefits is not included in the quantitative analysis. The 0.25% figure is based on the net of all the information gathered by the authors. It is a subjective figure and subject to differences in opinions. The inference should be that the 0.25% figure is simply a guide and more appropriately viewed as a spectrum. In the worst case scenario, none of the indirect benefits would be realized. In a more realistic scenario, indirect benefits would be realized. The quantitative analysis would then be numerically more in favor of the CBA project as a cost effective endeavor.

The future expansion of the CD-ROM can be analyzed for additional payoffs. EMC's efforts are presently directed toward the addition of graphic images to the CCB package. This addition will make the CCB package a complete and independent specification



writing package when available in CD form. This addition will also enhance user benefits by allowing images of standard drawings to be placed on the CD-ROM. EMC is also helping to develop an indexing system for easy retrieval of illustrations as opposed to text. This is a feature not yet available in the CCB package. Such offshoots of the adoption of the CD-ROM technology can provide additional benefits. This example is but one of many and it is mentioned here to emphasize that the CBA above was a limited focused one used to exemplify an engineering application of CD-ROM.

## VI. CONCLUSION

### A. OVERVIEW

This thesis has described the status of laser technology application and its use in the DOD construction arena. This was done by:

1. describing the present and expected uses of laser technology.
2. describing the application of optical discs to construction standards within DOD.
3. analyzing the CD-ROM Construction Criteria Base (CCB) project within NAVFAC.

The analysis of the CCB project vis-a-vis the various forms of laser technology available should provide insight as to whether it is properly being applied.

### B. CHAPTER SUMMARIES AND CONCLUSIONS

Each of the preceding chapters contains information relevant to the recommendations that follow. The chapter highlights along with conclusions drawn from each are given below.

#### 1. Current Technologies and Applications

It is important to understand the state of the art so that decisions can be made from a sound knowledge base. There are many forms of laser technology applications. Although the 4.72 inch, 600 MByte CD-ROM appears to be favored in most business applications, the characteristics

of the others must be assessed as well. Each application scenario is different. Therefore, the pros and cons of all the relevant alternatives must be considered before deciding on the use of laser technology over existing methods. Within that technology, there are likewise alternatives that need to be addressed in order to make a proper choice.

Laser discs edge into the domains of other storage media but do not replace them. Therefore, it is not proper to consider laser discs as the data storage and sole manipulation media of the foreseeable future. They serve a definite purpose and they serve it well. Those strong points should be cultivated. They should be considered in conjunction with other data storage media and not necessarily in place of.

The "read-only," "write-once," and "erasable" are the major categories of optical technology. All of the discs produced within each category have large memory capabilities. All provide savings in physical space needed for data storage, in distribution costs and in data retrieval. All can be read at independent and remote workstations. Their differences separate them into their respective niches of use. Additionally, their differences with other forms of data storage and manipulation also add to their specialized uses.

Prerecorded or read-only discs are well suited for both the entertainment and business sectors. In addition to

the general features listed above, these discs provide the users with data which may be used but not altered. Videodiscs are the prime example in the entertainment industry. CD-ROM is the prime example in the business sector.

The CD-ROM is a good candidate technologically for the storage and distribution of ubiquitous construction standards. Software is available to search, retrieve and manipulate data. Special needs can be addressed as well. Hardware is also economically priced. The primary tool, the microcomputer, serves multiple functions and readily adapts to the CD-ROM. Additionally, the CD-ROM readers have been improving in performance and decreasing in cost. An average price of \$500 per reader is in the near future.

The remaining direct investment costs of this technology then are data collection, adaptation of the data for use and publishing costs. Obviously, the wider the use of this centrally prepared and distributed data base the less the unit cost per user.

CD-ROM has limitations which must be kept in mind. For instance, it may be desired to distribute a limited amount of data which is regionally generated and regionally used. Or, construction standards that are unique to that particular region only. The users may have need of both the ubiquitous standards as well as the local ones. If there is sufficient usage, then it may be justifiable to purchase a

write-once desktop publishing system. It would save the fixed costs associated with making each CD-ROM glass master from which multiple copies are made. A break-even point analysis would indicate the required usage rate to make the higher investment cost in the write-once equipment pay off against the CD-ROM.

The write-once has already been touched upon above. In addition to those considerations, the issue of interoperability must be considered. The varied sizes of the discs and the proprietary nature of the write once read many (WORM) systems should be approached with caution. The lack of standards or a market leader that sets standards is a problem.

When dealing with standards, it seems absurd to use a technology which is without its own standards. It is proper to remember that there are specific applications where WORM may be the economically attractive alternative. One such example in DOD was given above.

Beyond standards, archival data dealing with construction projects are a good target for WORM application. An example of this is the voluminous contract files. DOD construction contracts are especially prone to large numbers of documents for a variety of reasons. Two reasons for this are audit trails and personnel turnovers. The correspondence files and payment records for even minor contracts can be several inches thick. It may be more

economical to retain such records on a laser disc using scanning techniques. Only a limited number of copies may be necessary since such archival data would be of interest only to the local constituency. The glass mastering and reproduction techniques may be prohibitive in cost in comparison to the write-once. Multiple uses of WORM technology may also help spread the high investment costs of \$100,000. That would reduce the costs associated with individual applications.

The erasable disc is not yet a viable product. The permanent nature of etching the surface of the disc makes it difficult to reverse the process. Within the context of DOD construction, the value of the erasable disc is mitigated by the relative novelty of laser technology in general. Its future applications should not be ignored though.

If the erasable disc works similar to the magnetic floppies of today, then it may become a very useful tool in the construction business.

One of the near certainties of the construction trade is the inevitability of changes during the execution of a contract. These can be caused by a variety of reasons. The plans and specifications may include previously undetected errors. There may be unforeseen site conditions which may require additional work. There may be requested changes due to shifts in requirements. There may be scheduling changes due to changes in priorities. These are

but a few examples of the things which precipitate alterations in plans. Changes must be documented and drawings updated accordingly. These "as-built" drawings are not only necessary for the project at hand but for future projects dealing with the same site. Erasable discs may be of great benefit in such cases because the entire data base do not need to be reread onto the new disc. The necessary changes may be made and the project updated on the original disc. This would also eliminate bulky drawing racks.

## 2. Laser Technology in DOD Construction

There are several applications of laser technology within the purview of DOD construction. This thesis has described and analyzed one of them, the CCB (Construction Criteria Base) project. Prior to analyzing this test platform, the basis of the two relevant alternatives were described.

The status quo of standards libraries in NAVFAC is a combination of paper, microfiche and microfilm. All existing government and nongovernment standards have a combination of these storage media. They are available from several sources with response times of two days to four months.

The CD-ROM, on the other hand, proposes to combine them all on one disc it will then be updated quarterly and distributed from a central location. The first phase

includes placing all the following government documents on one CD [Ref. 22]:

1. NAVFAC guide specifications.
2. Corps of Engineers (COE) guide specifications.
3. NASA guide specifications.
4. Veterans Administration guide specifications.
5. 100 military specifications.
6. NAVFAC design manuals.
7. SPECSINTACT software package for specification writing.
8. Search and retrieval software.

This endeavor is about one-third completed. The CD distribution is underway as is the initial training and use of the system by the Engineering Field Divisions (EFDs).

### 3. Analysis

The analysis chapter identifies a model for making a decision. The various results are addressed and conclusions identified.

The CCB evaluation included, among other things, a cost-benefit analysis. That analysis was based on quantifiable factors identified in previous reports and in field observations of the authors. The figures clearly favor the use of CD-ROM as the library medium for government standards. The benefits were conservatively estimated. It is concluded, for instance, that no real savings are realized for some time after the installation of equipment and initial training. Several reasons account for this:



1. People are busy with their present workload and cannot spend time experimenting with a new system.
2. People are hesitant to try anything new. This is particularly so of individuals who are set in their ways and who possess a "too old to change" mentality.
3. A sample or "dummy" set of contract specifications may need to be drawn up by the supervisors for people to work through on an "as time allows" basis. The lack of deadline pressure is helpful when learning a new system but can take months to complete.
4. The learning curve proficiency of each individual must be evaluated.

Accordingly, zero benefits were included for the first of the five year test period. It is believed that the actual learning curve is steep in that the system is not difficult to learn. Once the first year of adjustment is over, it is believed that a relatively steady flow of benefits will be recognized.

No particular difficulties are seen in the qualitative costs associated with the proposed system. It is believed that the qualitative benefits far outweigh their respective costs. Two of these benefits are: reduced legal fees due to the increased accuracy of the specifications under this new system; and reduced numbers of change orders necessary to complete a project. This analysis is qualitative in nature because no project has been completed and analyzed as of the time of this thesis.

The second phase of the CCB project evaluated is proposed to include the nongovernment standards. The quantitative analysis was very limited there due to the

unavailability of information from the various non-government standards bodies (NGSBs). Additionally, the constraints involved in this phase are of concern. There are legal and contractual constraints that must be overcome to get the consent of the several dozen NGSBs. Assuming that those constraints are succumbed, there will be the continuous concern of dealing with all of the NGSBs to provide updates.

#### C. RECOMMENDATIONS

Six specific recommendations are provided in this thesis. They are presented below.

##### 1. CD-ROM is a Valuable Asset to DOD Construction

The test platform used for analysis was the CCB project which is endorsed by most of the military services within DOD. The benefits that could be quantified for the NAVFAC test case showed an overwhelming support for the use of CD-ROM as the library medium for government standards. The qualitative aspects of the analysis are also considered to favor the CD-ROM. The proposed project is therefore considered worthy of continued support.

##### 2. Expand CD-ROM Use to the ROICC/PWDs

The field offices can benefit from the CD-ROM package. The contract specifications are easier to retrieve and to read. These field offices are often times at remote locations and are run with a small number of personnel and an equally small budget. They often cannot afford to

purchase or maintain the huge amount of standards libraries discussed in this thesis. Many have already made the move toward using microcomputers as a cost curbing measure. The \$550 subscription to CCB through NIBS would be affordable and welcomed.

3. Consider Nongovernment Sources for Nongovernment Standards

The addition of nongovernment standards to the CCB package requires further study before commitments are made. There are few cost figures available. Technological, legal and cooperative barriers exist as described above and in the preceding chapter. There is also some question as to the benefits such an addition would provide. Engineering Field Divisions, for instance, use other NGSB standards also in preparing contract specifications. They are therefore likely to continue present subscriptions for complete sets of NGSB as opposed to eliminating them in favor of a partial set of nongovernment standards provided by CCB.

On the other hand, the 90% or so of nongovernment standards used in DOD construction would be provided by the CCB package. It would reportedly contain those standards referenced by the guide specifications and shown in Figure 16. This would obviously be of great value to the smaller field offices such as the ROICCs. They normally do not carry the many volumes of non government standards libraries. The inclusion of the majority of those used on a daily basis on the CD-ROM would be beneficial to them. It

would save time in obtaining most standards and would save project time by providing the ROICC office with easy reference to the requirements of the construction contract at hand. It would save time in maintaining most publications at the field through quarterly updates.

There is also an alternative to making the non government standards part of the CCB package. There are private firms, such as Information Handling Services (IHS) of Colorado, who specialize in making and selling such information. They may be commissioned to produce a CD with the desired data on it. This would eliminate many of the obstacles of trying to do the work in-house. The cooperative effort on the part of all the relevant NGSBs would still be required. The technical drawback in such a case would be a second disc and possible incompatibility with CCB software.

A proper evaluation of this added step should include all the considerations listed in this thesis, particularly those provided just above. No additional specific recommendation will be given here because of lack of sufficient data.

#### 4. Expand CCB Use in the Government

The CCB system has been shown to be beneficial and desirable. It is a cost saving tool which already has the endorsement of several sectors of DOD and other government agencies. It is recommended that other government agencies

be encouraged to make use of the program. Within DOD, it is recommended that the Air Force be encouraged to fully support the program through use of the CCB CD-ROM.

5. Increase Research into Use of Laser Technology

There are a variety of possible candidate areas within construction which can use laser technology. The standards are one such area. Other libraries may benefit from CD-ROM or other laser technologies. Some examples are: Cost standards, computer standards, Computer programs, as-built records, training programs and general archival data.

D. SUGGESTIONS FOR FURTHER RESEARCH

There are many areas of further research in the laser technology field which may be conducted. The technology is developing at a good pace providing new improvements continuously. Research may be done to determine the feasibility of CD-ROM use in other areas with libraries of data. Several have been mentioned in the recommendations above, including archival data.

## APPENDIX A

### FORMAT FOR ABBREVIATED SYSTEM DECISION PAPERS (ASDPS)

1. Need. Outline the need for engineering microcomputers as related to specific elements of the activity's mission and their priority relative to other needs. Summarize the functional requirement and the information dependent tasks in detail. Describe the current method and evaluate the impact on operations of maintaining the status quo capability.
2. Proposed Solution. Propose a solution describing the generic specifications for hardware and software intended to satisfy the information processing need and identify various assumptions and constraints considered in the selection. Indicate milestone schedule of planned events, most importantly the target date (FY) for acquiring each microcomputer and implementing the various applications outlined in the previous section.
3. Other Alternatives Considered. Summarize other alternatives considered both feasible and infeasible and explain why each is inferior to the proposed solution of microcomputers.
4. Cost and Benefits. Summarize projected costs considering both recurring and non-recurring (hardware, software, personnel, facilities, training) of each of the alternatives in becoming an operational system and identify the expected benefits (improvement to functional unit, cost savings, etc.). Give cost benefit rationale for selecting the commended alternative.
5. Interface Considerations. Describe planned and potential interface with systems, procedures internal and external to the organization. Indicate anticipated advantages or problems associated with system interfaces.
6. Funding. Are there funds available to support the life cycle costs of the selected alternative? Identify the source and type of funding.

7. Other Comments. Include any additional information that will facilitate understanding and evaluating this ASDP.

8. Joint Signatures.

Submitted by: \_\_\_\_\_ Date: \_\_\_\_\_

Approved by: \_\_\_\_\_ Date: \_\_\_\_\_  
NAVFACENGCOM Code 04M

\_\_\_\_\_  
NAVFACENGCOM Code 011 Date: \_\_\_\_\_

COMPUTER RESOURCES ACQUISITION (ASDP SUPPLEMENT)

1. Computer Resource Identification. Describe the requested computer resources (hardware, software, services, etc.) in generic terms, or specifically if specific items are requested.
2. Location. Specify the intended location(s) of the requested hardware or software. Include activity address, building, number, room number, and organizational code(s).
3. Point of Contact. Specify name, phone number, and activity code of individual for point of contact.
4. Systems Life. System life will be five years for purposes of this procurement.
5. Cost. Prices will be provided at a later date when procurement method has been confirmed. Use enclosure(4) as a basis for cost estimates to be used in the cost/benefit analysis.
6. Computer Hardware and Data Communications Interface Requirements. Specify all computer hardware and data communications interfaces. Specify data communications equipment requirements and include the cost of such equipment.
7. Software and Maintenance Support. Specify all associated software and maintenance support required (e.g., on-call five days a week from 0800 to 1700 local time, or per call for parts and labor as required, etc.). Specify known costs for required maintenance plan or estimated costs if charges are variable such as for a per call maintenance plan.
8. Site Preparation. Ensure that adequate power and telephone receptacles are available.
9. Lease/Purchase Analysis. This equipment will be purchased, therefore, no lease/purchase analysis will be required.
10. Estimated Delivery Requirement. Provide an estimate of the required delivery date of the requested computer resources. "ASAP" is not acceptable, a reasonable, actual calendar date must be provided (i.e., month and year).



11. Computer Hardware Released. Identify the computer hardware to be released as a result of this acquisition, and provide a projected release date or state not applicable (N/A).
12. Method of Acquisition. This information will be determined at a later date. All sole source acquisitions of computer resources shall be forwarded to NAVFACENGCOMHQ (Code 011) for action or disposition.
13. Privacy and Security Requirements. Insure that all provisions of the Privacy Act are addressed and complied with. Provide a statement either that privacy provisions are or are not applicable.

## APPENDIX B

### GLOSSARY OF COMPUTER TERMS

ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange. It is the standard table of 8-bit digital representations used to transmit information to a printer, other computers, or other peripheral devices.
Bit	Binary digit. The smallest part of information in binary notation. A bit is written as either 1 or 0 and represents either the on or off variation of voltage.
Buffer	An auxiliary storage area for data. Many peripherals have buffers used to temporarily store data that will be used as time permits.
Byte	A group of eight bits of digital data which is processed together. A byte can have 256 (or $2^8$ ) possible combinations of 8 binary digits.
CAV	Constant Angular Velocity. A technique that spins a disc at a constant speed, resulting in the inner disc tracks passing the read/write head more slowly than the outer tracks. This results in numerous tracks forming concentric circles with the storage density being the greatest on the inner track. (See also CLV.)
CCITT	Acronym for the French name of the Consultative Committee on International Telephone and Telegraph. CCITT issues the standards for data compression techniques such as CCITT Group 3.
CD	Compact Disc--See CD-ROM.
CDI	Compact Disc Interactive. Physically identical to the CD-ROM disc, however, with emphasis on the interactive presentation of video, audio, text and data. A self-contained multimedia system expected to operate in conjunction with home entertainment equipment.

CD ROM	See CD-ROM.
CDROM	See CD-ROM.
CD-ROM	Compact Disc--Read Only Memory. A computer peripheral capable of storing large amounts of data which are placed on the disc at the time of manufacture.
Chip	The term applied to an integrated circuit that contains many electronic circuits. A chip is sometimes called an IC or an IC chip. The name is occasionally applied to the entire integrated circuit package.
CLV	Constant Linear Velocity (as opposed to CAV). Used with CD-ROM to keep the data moving past the optical head at a constant rate. In order to accomplish this, the rotational speed of the disc must vary, decreasing as the head moves from the inner tracks toward the outer perimeter. The range is approximately 500 to 200 rpm for a CD-RPM disc drive.
Code	A method of representing data in a form the computer can understand and use.
Command	A code that represents an instruction for the computer.
Density	The closeness of space distribution on a storage medium such as a disc.
Disk Operating System--DOS.	A program or programs that provide basic utility operations and control of a disk-based computer system.
Disc Preparation--	Providing certified tapes and shipping containers for customer data. Scanning input tapes for data integrity and cleaning up minor problems, building a directory (High Sierra or customer), putting the data in proper format for the mastering center user.
DOS	See Disk Operating System.
DRAW	Direct Read After Write. A write once optical disc technology (see also WORM), an error control technique; however, it is unable to be used with CD-ROM.

EBCDIC            Extended Binary Coded Decimal Interchange Code. An 8-bit code developed by IBM, and used primarily by IBM and its compatibles. The code is used to represent 256 numbers, letters and characters in a computer system. (See also ASCII.)

FCCSSAT           Federal Council On Computer Storage Standards and Technology.

GB                See Gigabyte.

Gbyte             See Gigabyte.

Giga               1,000,000,000.

Gigabyte           1,000 megabytes, or 1 billion ( $10^9$ ) bytes.

Glass Master      The original glass disc upon which the digital information is burned with a laser. From it are formed the "stampers" which in turn are used to produce the numerous discs, usually by an injection molding process.

Hardware           The physical computer and all of its component parts, as well as any peripherals and inter-connecting cables.

High Sierra Group--An ad hoc working group of CD-ROM service companies, vendors, and manufacturers which has been a prime source of activity in the setting of standards for CD-ROM data format and compatibility. The group was named after its first meeting place--the High Sierra Hotel at Lake Tahoe. The group first met in 1985.

IC                 Integrated Circuit.

Indexing           The actual processing of all records according to the layout and the building of the index file. Indexes permit the computer to rapidly locate data without searching through the full body of data. Generally, a data item is searchable only if it is indexed.

Indexing Layout--Design of the customer database according to the criteria established by the customer. This is done only when the database is first processed or changes are made.

Indexing Set Up--Tape handling, resource allocation and loading the layout programs on the indexing system.

Instruction A program step that tells the computer what to do for a single operation in a program.

Interface A device that serves as a common boundary between two other devices, such as two computer systems or a computer and peripheral.

Jewel Box The plastic container in which the CD-ROM disc is generally stored.

Jukebox See Optical Jukebox.

K Abbreviation for Kilo.

KB See Kilobyte.

Kbyte See Kilobyte.

Kilo A prefix meaning (1) 1000 when used in a mathematical expression; or (2)  $1024 \cdot 2^{10}$  when used as a unit measure in computers. As an example, 16K would equal 16 times 1024 or 16,384.

Kilobyte A unit of measure in computers that equals 1024 bytes.

LAN Local Area Network.

Land The reflective area between two adjacent non-reflective pits on a disc. The transition from pit to land or land to pit represents a binary 1. (See also Run.)

Load The process of entering information (data or program) into a computer, from a keyboard, disk, or other source.

M Abbreviation for Mega.

Machine Language--A programming language consisting only of numbers or symbols (binary code) that the computer can understand without translation.

Mastering The entire process involving the scheduling of the mastering center, managing artwork and packaging issues and Q.A.ing all replicas for data integrity and readability.

MB	See Megabyte.
Mbyte	See Megabyte.
Mega	1,000,000.
Megabyte	1,000 Kilobytes, or 1 million ( $10^6$ ) bytes.
Metal Mother	The negative mold created from the glass master which is in turn used to stamp the numerous discs. Often called a "stamper."
Micron	One square micron, the area occupied by 1 bit on a CD-ROM. One millionth of a meter.
Microsecond	One 1/1,000,000th of a second.
MS-DOS	The disk operating system used with IBM computers and their compatibles.
OCR	Optical Character Recognition. Generally used in reference to a device capable of scanning printed material into a digital form.
OD3	Optical Digital Data Disc.
Optical Jukebox--	A store and read mechanism capable of storing and accessing multiple CD-ROMs. Accessing is generally accomplished by mechanical means after which the discs are placed on a single reader (disc drive) for use.
OROM	Optical Read Only Memory.
Parity	A method of error detection that uses a percentage of redundant data to verify the user's data.
Parity Check	A test to help determine data's validity. Specifically, this test determines whether the number of zeros and ones that the binary digits of a byte of data represent is odd or even.
Pit	The microscopic depression in the reflective surface of a disc. The pattern of pits represents the data being stored on the disc. (See also "land.") The light from the laser used to read the data is reflected back from the lands, but scattered by the pits. A

typical pit is about the size of a bacterium--  
0.5 by 2.0 microns.

- Pixel            A picture element in a video display; the minimum raster display element, represented as a point with a specified color and intensity.
- Platter          Generally used in reference to the larger (12") optical discs. Sometimes in reference to a single layer in a magnetic disc pack.
- Premastered Tape--A magnetic master tape that contains all data and control codes that are to be recorded on an optical master disc via laser beam modulation.
- Premastering    In CD ROM, a data-formatting process performed on each block of user data. The process determines the sector address and adds synchronization information. If the format is to be Mode 1, 288 bytes of error detection and correction data are calculated, and this data is added at the end of each sector to ensure the full recovery of user blockdata.
- Query Language--In database management systems, an alternative to conventional programming languages that enables users without formal training in algorithmic thought to formulate ad hoc information-retrieval requests using English-like phrases.
- RAM             Random Access Memory. Semiconductor memory circuits used to store data and programs in information processing systems.
- Replication     The process of making multiple copies of a CD ROM.
- R/W/E           /Read/Write/Erase--An alternative title for erasable discs.
- Run             The distance between transitions either from land to pit or pit to land. The distance represents two or more zeros (see also Land).
- SASI            Shugart Associated System Interface--The precursor to SCSI.

SCSI	Small Computer Systems Interface--A Complete 8-bit parallel interface bus structure with rates up to 4 Mbytes/sec., that are subordinate to the rest of the system architecture. Up to 8 systems and peripherals may be connected to the same bus.
Seek	To position the read head of a mass storage unit in the correct location to read a particular file or piece of information. On a CD ROM drive, this generally requires also altering the rotational speed. Because seeking data on a CD ROM is time-consuming when compared to seeking on magnetic-disk media, the number of seeks required to find the desired information is an important determinant of overall CD ROM system performance. The High Sierra Group's proposal file format and directory structure provide for opening any file on a CD ROM disc with only one or two seeks.
Software	A general term that applies to any program (set of instructions) that can be loaded into a computer from any source.
Sort	To arrange (or place in order) data according to a predefined set of rules.
Stamper	See Metal Mother.
Substrate	The base material from which a disc is made, generally a strong and transparent polycarbonate plastic.
Track	A linear, spiral or circular path on which information is placed, or found. The portion of a disk that one read/write head passes over to extract data. Track density is measured in tpi (tracks per inch).
Tbyte	Terabyte or 1,000 gigabytes ( $10^{12}$ ).
WORM	Write Once Read Many (occasionally seen as Write Once Read "Mostly" or "Multiple").



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