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Common Mapping System Media Study

By

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The Common Mapping System (CMS) defines data formats and standard distribution media for the storage, interchange, and retrieval of mapping, charting, geodesy, and imagery (MCG&I) data. A variety of DOD systems are expected to adopt the CMS standard, including mission planning, intelligence, and avionics systems. The distribution media types supported by CMS will significantly impact the utility and cost of CMS for these systems. This paper presents the results of an investigation into the attributes of candidate distribution media for CMS, describing cost and production time tradeoffs. We conclude that there would be value in adding compact-disk-read-only-memory (CD-ROM) to erasable optical disk (EOD) as supported distribution media to meet the needs of the Air Force Mission Support System (AFMSS). Additional media types may be necessary to support the requirements of other systems.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION

Historically, mission planning systems were developed and acquired separately for each major command. Although each of these systems needed similar types of mapping, charting, geodesy, and imagery (MCG&I) data, the developed systems generally had different data formats, used different storage media, and executed unique transformations on the data before using it internally. The next generation of mission planning systems will evolve towards common hardware, software, and data packaging. A key goal is to facilitate data-sharing among systems through the use of standardized data formats and distribution media. To this end, the Common Mapping System (CMS) defines data formats and standard distribution media for the storage, interchange, and retrieval of MCG&I data. A variety of DOD systems are expected to adopt the CMS standard, including mission planning, theater-level C^3, intelligence, and avionics systems. The adoption of a single standard will allow future systems to share MCG&I data and share the cost of producing MCG&I data sets. This paper focuses on the CMS media standards, which will significantly impact the utility and cost of CMS for these systems.

1.1 BACKGROUND

The CMS interface standards are specified by the CMS Interface Control Document (ICD) [1]. The CMS ICD defines specific media, which are approved for the distribution of CMS data and also specifies the physical formatting, volume formatting, file organization, etc., for each approved distribution media. Until recently, the CMS ICD allowed only erasable optical disk (EOD) media; but an 8 mm tape and a 4 mm tape have also been included in the most recent ICD revision. Efforts are also underway to add CD-ROM and possibly other media. In order to share data and data production costs between CMS systems, a coherent CMS media strategy based on a limited set of "standard" media types is desirable. This paper proposes such a media strategy that offers a cost-effective solution that will meet the requirements of many CMS systems. Using AFMSS as a specific example, we illustrate the advantages of our recommended dual-media solution. Other CMS systems should be encouraged to adopt this standard media strategy, except where unique requirements demand a unique solution.

1.2 SCOPE

Media alternatives for CMS are evaluated based on several important criteria. Since media selection depends on the concept of operations and other attributes of specific systems, media are compared over a range of system parameters.

We expect that a variety of systems with different operational requirements will use CMS data. In this paper, we use the term "CMS system" to refer to any system that uses CMS-compliant data to meet its requirements for MCG&I data. Many of these systems require that the distributed CMS data be "compressed" to minimize the storage requirements. In this paper, we use the term "compression" to refer to a variety of available software techniques (e.g., spatial reduction, color reduction, image enhancement, vector quantization) that result in reducing the storage requirements for MCG&I data while maintaining acceptable visual quality. We assume a nominal compression ratio of 48:1 for maps and 4:1 for imagery. The conclusions reached in this paper will apply equally to similar compression ratios (i.e., 55:1 for maps), which are currently being considered for CMS.

Section 5 presents examples and scenarios based on AFMSS, since AFMSS will be a prime consumer of CMS data. While many other systems will be well served by the media strategy recommended in this paper, we recognize that the unique requirements of other systems may favor an expanded media strategy including other media types.

1.3 ORGANIZATION

Section 2 identifies the generic requirements for CMS distribution media.

Section 3 presents an overview of the characteristics of those media that are applicable to CMS.

Section 4 compares the candidate CMS media discussed in section 3 based on the requirements described in section 2.

Section 5 describes specific requirements and recommendations for the AFMSS program.

Section 6 presents conclusions and recommendations of the CMS media study.

SECTION 2

DATA DISTRIBUTION REQUIREMENTS FOR CMS

To compare the costs and benefits of various CMS media alternatives, a natural first step might be to predict how CMS data will be distributed (i.e., how much data and how often). An accurate prediction would be system-specific and would require knowledge of exactly what map products, how many copies, what geographic coverage, etc., will be required for future peacetime and wartime activities. We would also need to consider how map and imagery products will evolve and how often they will be updated. Since such an "across-the-board" prediction is not possible, we will establish the range of values for each of the key parameters identified above and then evaluate the attributes of the various media across the range of these parameters.

2.1 CMS DATA OVERVIEW

A brief overview of the major CMS data types will be presented. For further details, reference [1] should be consulted. Our intent is not to cover details of the content or format for CMS data types, but rather to provide a basic understanding of the key CMS data types and an appreciation for storage requirements.

2.1.1 Raster Products

The CMS raster products are based on a two-dimensional array of data points that have been processed so that the sample points are spaced at constant latitude and longitude intervals. Arc Digitized Raster Graphics (ADRG) is produced by Defense Mapping Agency (DMA) by scanning paper charts to produce digital raster map products. DMA produces several different types of paper map products at map scales from 1:5M to 1:50K. Figure 1 shows the approximate geographic coverage for map scales 1:5M to 1:500K. Each of the actual paper maps shown in figure 1 are 40 x 60 inches and the scanned digital version occupies 464 Mbytes.

Note that figure 1 only shows ADRG products down to the TPC (1:500K) scale, but also available are the JOG (1:250K) and TLM (1:50K). If JOG and TLM paper charts were of the same physical size as a TPC, they would only cover 1/4 and 1/100th of the geographic area respectively. Uncompressed ADRG TLM data for a single geocell (a 1 degree latitude by 1 degree longitude area) will occupy about 1.4 Gbytes. Arc Digitized Raster Imagery (ADRI) provides the same geographic scale and has the same storage requirements as an ADRG TLM but is derived from satellite imagery rather than a paper map. Digital Terrain Elevation Data (DTED) provides a two-dimensional array of terrain elevation data points. DTED data is produced at two scales (100 meter spacing and 30 meter spacing) that require either 3 Mbytes or 27 Mbytes of storage per geocell.

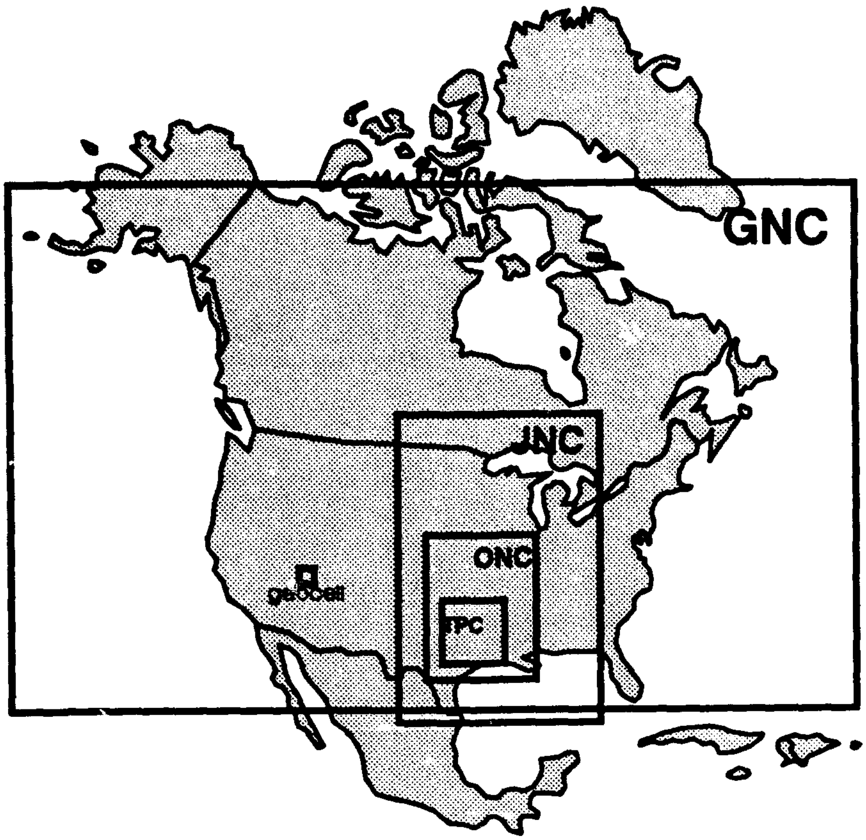

Figure 1. Approximate Geographic Coverage of GNC (1:5M) through TPC (1:500K) Chart Series

The raster structure of both ADRG and ADRI data sets makes them well suited to digital image compression techniques. The CMS ICD will define one or more approved compression techniques for distributed CMS data. It has been shown that adequate map quality can be preserved for many applications while achieving a compression ratio of 48:1 or higher for ADRG and 4:1 for ADRI [2]. In calculating the storage requirements for CMS distributions, we will assume that distributed ADRG and ADRI are compressed at these levels.

2.1.2 Vector Products

Unlike raster products, the vector products reproduce geographic features by decomposing cartographic features into graphic primitives, such as: characters, lines, circles, and polygons. Currently, few vector map products are available; but emerging vector map products are expected to be widely available at many scales by the year 2000. Those products available today include: Digital Feature Analysis Data (DFAD) level 1, Digital Chart of the World (DCW), and World Vector Shoreline (WVS). DFAD characterizes cultural features by dividing the terrain into point features and polygonal areas with a corresponding surface descriptor (e.g., forest, rock, asphalt, water, etc.). Currently, DCW is a vector version of an ONC chart, reproducing nearly all of the ONC chart features using graphic primitives. Future versions of DCW will be expanded to include other chart scales. WVS provides only landmass outlines and international boundaries. DFAD level 1 data requires about 0.4 Mbytes of storage per geocell of coverage. Complete worldwide coverage of DCW and WVS requires about 2.5 Gbytes and 170 Mbytes respectively.

2.2 SIZE OF CMS LIBRARIES AND UPDATES

Although the concept of operations will differ somewhat among the various systems using CMS, many systems will share some common attributes. In many cases, the amount of maps/imagery required at each location will exceed the available on-line storage (i.e., hard disk) space by an order of magnitude or more. This means that an off-line "library" of optical disks, tapes, or other media must be maintained. During normal operations, selected library volumes may be mounted for on-line access, or alternatively, selected data sets may be downloaded onto a high-speed storage device (i.e., hard disk) for faster performance.

Maintenance of the CMS library will be accomplished by periodically distributing a set of "update media" to each CMS system. For those units whose area of interest does not change, the maintenance distributions will probably be fairly small, effectively replacing the entire CMS library only about once every 2-5 years. Depending on the concept of operations, the distributed update media may be used as direct replacements for media volumes in the CMS library, or the update media may be used to rewrite or overlay selected portions of the CMS library media.

Because these maps/imagery require large amounts of digital storage, each media library will be customized to contain only those data sets needed by a particular system at a particular location. The actual size of the CMS library will vary with different areas of interest and with different user requirements, but it will probably be between 20 and 70 Gbytes for typical installations. This estimated library size is based on the data shown in table 1 and assumes that all ADRG products are compressed. For each data category, the center column lists a range of coverage options and the right-most column shows how much data will likely be maintained at each CMS system. Maintenance of a library covering fixed geographic areas is assumed to require data updates amounting to about 20 percent of the total library size per year.

Note that actual library maintenance traffic may be much higher than 20 percent per year. This is because the area(s) of interest for particular units may change due to deployment, participation in military exercises, or for contingency operations. Under these circumstances, the geographic coverage of specific CMS libraries will change, requiring much larger update distributions.

Table 1. Expected CMS Library Size

Data Category (Partition)	Coverage Options (storage requirements for compressed data)	Expected Size of CMS library (Gbytes)
Global GNCs, JNCs, and WVS	entire world (1.7 Gbytes)	1.7
Regional DCW	entire world (2.5 Gbytes) GNC-sized area (0.2 Gbytes)	0.2 - 2.5
Area ONCs and TPCs	GNC-sized area (0.9 Gbytes) 2 JNC-sized areas (0.4 Gbytes) JNC-sized area (0.2 Gbytes)	0.2 - 0.4
Standard Local ADRI, DTED 1, DFAD 1, and JOG-A,	GNC-sized area (92.1 Gbytes) 2 JNC-sized areas (0.4 Gbytes) JNC-sized area (17.5 Gbytes) ONC-sized area (4.4 Gbytes)	17-35
Optional Local DTED 2, JOG-G, ATC, and TLM	GNC-sized area (154 Gbytes) JNC-sized area (29.2 Gbytes) ONC-sized area (7.3 Gbytes) no coverage (0 Gbytes)	0 - 30
Total		~ 20 - 70 Gbytes

Based on current thinking, the DMA will be responsible for producing a central archive of the source CMS data. In general, DMA will replicate, package, and send this data directly to the users' CMS systems using a standard distribution medium. In other cases, the source data will be sent to one or more CMS distribution sites, which will be responsible for replicating and packaging the CMS data. To insure maximum sharing of data among CMS systems and to simplify the library updates, a single distribution medium would be best; however, other factors may force the distribution sites to ship CMS data using several different media.

2.3 ATTRIBUTES FOR DISTRIBUTION MEDIA

Since large quantities of CMS data will be archived at multiple locations, this section will address those media attributes that are desired to facilitate the distribution, utilization, and maintenance of CMS libraries. Our intent is to define a minimum set of attributes that will meet the requirements of most CMS systems; however, we recognize that requirements of particular systems may demand unique media solutions.

2.3.1 Capacity

The media must provide adequate storage capacity to support the exchange of CMS data with various systems. An optimal media should provide adequate storage capacity at minimum size and weight. The capacity of each media volume will determine how frequently the user must interact (e.g., flip disks) when data is downloaded from the distribution media. To minimize user interactions and facilitate frequent data distributions, each volume should be capable of storing at least 20 compressed ADRG charts. Since most CMS systems will be exchanging compressed CMS data, the media should be capable of storing data in this format.

The required media capacity is also indirectly affected by the required visual quality of distributed CMS maps and imagery. Compressed CMS maps and imagery require significantly less storage space (i.e., approximately one 50th) as compared with the noncompressed source data; but, when the compressed products are uncompressed for display, visual quality will have been degraded slightly. To compensate for this degradation, image enhancement techniques (e.g., edge sharpening) can be incorporated into the compression processing. This technique is particularly promising for maps. When displayed on a workstation, maps that have been enhanced, compressed, and decompressed have been judged to provide better visual quality than the original source data.

We expect compressed data will offer acceptable display and print quality for most CMS systems; however, some CMS systems may require maps and imagery with the utmost visual quality that simply cannot be attained using compressed data. To meet the needs of these CMS systems, noncompressed maps and/or imagery may need to be distributed. Although any media can store either type of data, large scale distribution of noncompressed data is only feasible for those media with the highest capacities (and low cost per megabyte). Given adequate media capacity, CMS distribution media could contain selected maps and imagery at two or more "quality levels." If adequate capacity is not available, then a unique media solution may be needed for those CMS systems requiring maps and imagery of the highest quality.

2.3.2 Performance

For many CMS systems, performance will be a key discriminator among media. There are two characteristics that determine media performance: *access time* and *transfer rate*. Access time refers to the average time required to locate a random block of data on the media. Once the data block has been located, data can be read from the media at the transfer rate (usually expressed in Kbytes or Mbytes per second). For disk media, access times are generally measured in milliseconds; most of this time is spent moving the read/write head into position. For tape media, average access times may extend to several minutes due to the lengthy time required to advance/rewind the tape.

Many CMS systems will use the distribution media for downloading selected CMS products to an internal high-speed storage device (i.e., hard disk). For this application, media performance will be determined primarily by transfer rate. This is particularly true when a series of products stored sequentially on the tape or disk are downloaded. For these applications, the CMS distribution media should provide a transfer rate of 400 Kbytes/sec or more, which equates to 30 seconds per compressed ADRG chart.

For those systems with limited internal on-line storage (e.g., MSS IIA, AFMSS PMPS), the CMS distribution media may be used for on-line access. Charts, imagery, or other products will be accessed directly from the distribution media to support each display update. In this case, media performance will be determined primarily by access time. If the CMS media is to support timely display updates for these systems, then the media access time must be less than 500 milliseconds. Although not all CMS systems need to use the distribution media as an on-line resource, the CMS media strategy should provide for this capability.

2.3.3 Production Costs

A key cost driver for CMS will be the cost to master and replicate CMS media distributions. The possibility for media reuse, for read-write media, will also impact life-cycle costs. The media strategy for CMS distributions must remain cost effective across large variances in *replication quantity*. That is, the number of copies required for a given set of maps or images.

The reason that replication quantity influences the media decision is that specific media are cost effective only within a particular replication quantity range. This factor may favor support for multiple media types for CMS distributions, since a medium that is cost effective for mass replication may be cost prohibitive for small production runs. Those applications, like mission planning, requiring a mix of large and small production runs may need to consider a mixed media strategy.

For CMS data, replication quantity will vary significantly depen. ing on the map scale and geographic area covered by each chart. For example, nearly every CMS system will need a complete set of very small scale (large area) charts that support global navigation. On the other hand, a specific large scale (small area) chart will only be needed by those units or squadrons having a particular interest in the locality covered by the chart. Since there are ultimately expected be at least 1,000 deployed CMS systems, this means that replication quantity may vary from 1 to as high as 1,000 depending on the "popularity" of a particular data set. For this reason, an optimal media strategy for CMS must be cost effective for both small and large production runs.

2.3.4 Production Time

In addition to cost, the time required for producing CMS media must be considered. The distribution media strategy needs to support the timely production and distribution of CMS updates. This is particularly true for situations involving rapid deployment of forces where a small number of mission-specific charts, say 50, must be quickly produced and distributed to 50 or fewer units. Depending on the particular circumstances, these data sets may be required in as little as 48 hours.

SECTION 3

CANDIDATE DISTRIBUTION MEDIA FOR CMS

Based on the requirements for data exchange, we can evaluate candidate transfer media for this application. The first four sections describe media, which are of particular interest or promise for CMS systems. Other media, which were considered but were found to have more limited applications, are discussed in section 3.5

3.1 ERASABLE OPTICAL DISK (EOD)

For those applications that require very fast access times and exchange large unts of data (>1 Gbyte) between computers, the dominant medium for the next several ye ll be the erasable optical disk (EOD). These disk drives are also called "magneto optica)" drives, since they read and write data by exploiting the magnetic and optical characteristics of the media. Large amounts of data can be stored on convenient removable cartridges. Storage capacities of today's EODs will increase by a factor of 4x to 10x by the end of this decade. Current EOD cartridges provide a costly but powerful data transfer mechanism offering significant speed and capacity improvements over floppy disks and 1/4 inch cartridge tape.

The most common size EOD media today is 5 1/4 inches in diameter, and the drives are manufactured by several vendors. The drives conform to the standard 5 1/4 inch full-height form factor, but half-height models are expected in 1993. When installed internally, the EOD drive itself weighs about 7 pounds; external configurations require a separate enclosure, power supply, and fan, bringing total weight to around 10 pounds. The EOD media is similar in size to a 5 1/4 inch floppy disk but 1/4 inch in thickness and has a nominal weight of 6 ounces.

Vendor specifications indicate about 35-60 milliseconds seek time and 650 Kbytes/second transfer rate for reading, but our experience indicates that effective performance is about 200-400 Kbytes/sec, depending on drive manufacturer and device driver software. Writing is significantly slower with a nominal transfer rate of 200 Kbytes/sec. The unit costs range from $2,500 to $4,000 for the disk drive and about $120 for each optical cartridge.

One area that needs attention is compatibility of media and data formats. Several different, incompatible recording and formatting techniques are currently used among the vendors. A majority of the disk drives use the "continuous composite" recording format that has become an International Standards Organization (ISO) standard (ISO 10089). Draft ISO standards for a higher density format will be announced in 1993 and 1994 providing from 2x to 4x the storage capacity of today's EODs. The current format provides either 652 or 595 Mbytes per disk depending on sector size, UNIX systems being generally limited to the latter. Driven by user demands for compatibility, the ISO formats will eclipse the other proprietary formats in the next few years. The CMS ICD currently provides for 595 Mbytes of storage per EOD and specifies the ISO continuous composite recording format.

3.2 COMPACT DISK READ ONLY MEMORY (CD-ROM)

For applications requiring the distribution of large data sets (hundreds of Mbytes) and low-cost mass replication (hundreds of copies), the advantages of CD-ROM cannot be matched by any other medium. CD-ROMs have historically suffered from slow transfer rates compared to other disk drives, but recent trends indicate that CD-ROM transfer rates will soon be competitive with current EODs.

The data contained on a single CD-ROM is stored in a single concentric track of tiny bumps, or pits, which begins near the center of the disk and spirals outward. The radial distance between each turn of the spiral, called the pitch, is 1.6 microns. (A micron is one millionth of a meter.) The ability to store data in such a small area gives CD-ROM its high data storage density. One CD-ROM can hold about 680 Mbytes of data. The data is stored on a polycarbonate disk 120 mm (4.75 inches) in diameter and 1.2 mm thick with a weight of 14g. Large distributions of CD-ROMs can be packaged in paper or vinyl sleeves (analogous to a floppy disk), to minimize volume and weight. Unlike the EOD, the CD-ROM is one sided; the entire data volume is stored on a single side, so the disk never has to be flipped over.

A technology has recently been introduced that allows data to be written to individual CD disks, although the data cannot be changed once written. This technology is known under several names including: CD-Recordable (CD-R), CD-Write Once (CD-WO), and CD-Write Once Read Many (CD-WORM). Using special CD media and a much larger disk drive, individual CDs can be mastered. The recorded CDs can then be read by standard CD-ROM drives. The recordable CD disks cost about $100 each. Since this technology offers neither the economic advantages of CD-ROM nor the rewritability of EOD, it will not be discussed further.

3.2.1 CD-ROM Drives

A CD-ROM drive is required to read the data encoded onto a CD-ROM disk. Using a low powered laser, the drive is able to detect the pits recorded on the disk. These drives cost about $600 in single quantities and are designed to the standard "third-height" 5 1/4-inch form factor. When packaged in an external enclosure, these drives weigh about 8 pounds, including power supply. Due to the small physical drive size, CD-ROM drives may also be internally installed in workstations, and even some portable computers. The weight of an internally installed CD-ROM drive is about 3 pounds. For both the internal and external drives, data is relayed back to the host computer through a Small Computer Systems Interconnect (SCSI) interface.

The CD-ROM drives offer access times of about 300 milliseconds. Data transfer rates of these devices have generally been very slow, but improved "double-speed" drives with faster spin rates offer higher transfer rates. Vendor literature indicates transfer rates of about 300 Kbytes/second, but observed user transfer rates are closer to 200 Kbytes per second. An additional 2x improvement in transfer rate is expected in 1993 with the introduction of "quadruple-speed" drives, but no increase in data capacity per volume is expected for at least the next several years.

3.2.2 CD-ROM Production

CD-ROM disks can be mastered and mass replicated in a manner analogous to phonograph records. Development of a CD-ROM production facility dedicated to producing CMS data would be cost prohibitive, but commercial CD-ROM "publishing houses" provide CD-ROM production services at reasonable cost. For a nominal $1,500 fee, a CD-ROM publishing house will format and master the source data. The master can then be replicated at a cost of about $1.50 per disk. Turnaround time for this process is about 10 days from receipt of source data to delivery of CD-ROMs, but 1-day turnaround is available at about double the mastering cost.

The mass production of prerecorded CD-ROM media is a technically complex process combining controlled environments, specialized equipment, and highly refined materials. In the first phase, the source data is pre-mastered, which formats the data to conform to one of several formats, ISO 9660 being most widely used. Next, the data is encoded into a glass master using a high-powered laser. The glass master is a disk of highly polished optical grade glass coated with a layer of sensitive material. The glass master is then immersed in a nickel solution and a metal layer is deposited on the master through electroforming. The electroformed nickel disk (called a stamper) is then removed from glass master. The stamper is then trimmed, cleaned, and mounted into an injection molding press, forming one side of the mold cavity.

The replication process can now begin. For each production disk, the mold is filled with molten polycarbonate, which quickly congeals to form a clear disk. Each disk is then coated with a thin layer of aluminum through a vacuum metallization process. The metal provides a reflective layer, which is required to read data from the CD-ROM. A layer of protective material is added to protect the metal from corrosion and scratches. Finally, a label is silk screened to finish the disk.

3.3 HELICAL SCAN TAPE

For system administration functions, such as data backup, data archiving, and restoration, magnetic tape has long offered the best price/performance. Two tape technologies are available: 4 mm and 8 mm, with ISO standards 10777 and 11319 covering the respective data formats. The 4 mm tape, also known as Digital Audio Tape (DAT), was developed to meet the needs of the music recording industry but has more recently been adapted to storing other types of digital data. The 8 mm technology offers higher storage capacity, faster transfer rates, and lower cost per Mbyte as compared with 4 mm technology. Also, 8 mm technology is expected to achieve a 10x improvement in capacity in the next 5 years; whereas, 4 mm technology can only expect modest improvements since it is already operating near its physical limits. For these reasons, we will restrict further discussion to the 8 mm tape technology.

The 8 mm helical scan tape (also called Exabyte tape) offers the impressive storage capacity and low drive/media cost compared with other tape devices. Up to 5 Gbytes of data can be stored on each 8 mm tape cartridge. The tape cartridges measure 3.7 by 2.5 x 0.6 inches and cost about $15 each. The tape drives are designed to the standard full-height 5.25-inch form factor and are normally packaged in an external enclosure. The cost for these drives is generally about $3,000 in single quantities. Total weight for this enclosure, including power supply, is about 5 pounds. Data is relayed back to the host computer through a SCSI interface.

The 8 mm helical scan tape drives achieve high-data density by recording data in diagonal tracks on magnetic tape. The tape travels over read/write heads, which are mounted on a spinning drum aligned diagonally with the tape path. With the drum spinning rapidly and the tape passing over the drum slowly, the head writes data in a diagonal pattern corresponding to the pitch of the head, resulting in a high tape-to-head speed. Most tapes are 90 meters long, so activities that require significant tape movement (e.g., tape rewind, file searches, etc.) can take several minutes.

Nominal data transfer rates for 8 mm tape drives are about 500 Kbytes/second based on vendor specifications, which compares favorably with other media alternatives. At this rate, it takes nearly 3 hours to backup or restore an entire 5 Gbyte tape cartridge. By placing special file markers on the tape, the tape speed can be increased for file searches, but even at this rate, it may take up to 2 minutes to access a given file. While well suited to data archiving and backups, the 8 mm media should not be used for applications requiring quick access to stored data.

3.4 VIDEO LASER DISK

The video laser disk (VLD) is the only medium capable of storing copious amounts of video data and providing random access to the data. Unlike the other media previously described, the VLD stores analog information, not digital. Although these products are predominantly used for entertainment and educational applications, the VLD has been used in a variety of intelligence/planning systems and has been proposed as a storage medium for MCG&I data. For CMS data, the VLD medium holds the promise of providing high data capacity, improved display quality, and fast on-line access. It is important to recognize that the VLD can only store video information (i.e., pictures), so it can only store pixel-based information (e.g., ADRG and ADRI) but cannot store non-pixel data (e.g., vector maps, elevation data, databases, ASCII data, etc.). In particular, we should note that compressed raster data cannot be stored on a VLD because, in its compressed form, this data must be treated as non-pixel data. This means that the VLD is incompatible with those systems that need to exchange compressed raster data (e.g., moving map systems). In addition, because the VLD is only suitable for storing raster data, only raster-based MCG&I products could be distributed on the VLD medium; the rest would require EOD or some other digital storage medium.

Three different VLD technologies are available: read-only (ROM), Write-Once-Read-Many (WORM), and rewritable. The cost of drives for reading/writing to VLDs varies significantly with VLD-ROM drives at $800 - $1,200, VLD-WORM drives at $5,000 - $10,000, and VLD-rewritable drives at $20,000 - $30,000. Like CD-ROMs, the VLD-ROM disks are produced at a dedicated commercial production facility at a mastering cost of $2,000 -

$6,000 per master and a replication cost of $15 - $20 per production disk. Actual cost is determined by the speed with which the VLD-ROMs must be produced, with 1-week turnaround offering lowest cost and same-day turnaround being highest cost. Media costs for both the WORM and rewritable VLDs are very high at $250 and $1,200 per disk, respectively. Production time to produce a single WORM or rewritable disk is about two days, but duplicate disks can be made through a disk-to-disk copy in about one hour per disk.

The VLD stores analog video information as either real-time video or a series of individual still frames. There are two formats generally available: constant angular velocity (CAV) (also called "standard play") and constant linear velocity (CLV) (also called "extended play" and "industrial format"). The CAV format is potentially relevant to CMS systems because it supports random access to any frame on the disk. Using this format, each VLD is capable of storing 54,000 video frames on each side. If the VLD is used as a storage medium for CMS data, each of these frames would correspond to a small patch of MCG&I data.

Each VLD frame is recorded as an analog video signal, providing 525 lines of vertical resolution. The horizontal resolution of most VLD recorders and players is around 400 lines. VLD-ROM technology uses the National Television System Committee (NTSC) encoding standard that combines a wide band signal carrying luminance information and a narrower-bandwidth chrominance signal. The WORM and rewritable drives offer much better picture quality by recording separate component signals. Based on WORM technology, it has been found that each VLD frame is capable of storing a small "patch" of MCG&I data of roughly 640 x 480 source pixels while maintaining good quality [3].

The VLD could be used to provide raster-based CMS data to a computer system by adding a frame grabber board to the computer. The frame grabber board converts an analog video signal into raster digital data. The amount of time required for the frame grabber board to "grab" a signal frame varies significantly. Inexpensive frame grabbers ($1000) may take several seconds, while real-time frame grabbers ($8000) are able to grab frames at the NTSC rate of 30 frames per second.

3.5 OTHER MEDIA

Several other distribution media alternatives were considered for use as standard CMS distribution media. In order to focus attention on those media that would meet the requirements of a wide range of CMS systems, the following assumptions were made. First, we assumed that the capacity of each physical media volume should be at least 200 Mbytes. This corresponds to 20 compressed charts at about 10 Mbytes per chart. This will keep the number of physical volumes in each CMS library at a manageable level and also minimize operator interactions when these library volumes are downloaded to on-line storage. Second, we assumed a required transfer rate of at least 400 Kbytes/second for reading data. This corresponds to a transfer rate of 25 seconds per compressed DMA chart. Finally, we focus on the most cost-effective solutions by restricting consideration to media solutions with costs of less than $200 per Gbyte. The full range of media considered are shown in tables 2 through 5.

Table 2. Primary Storage Drives

Media	Capacity (Mbytes)	Access Time (msec.)	Drive Cost	Media Cost	Transfer Rate (Kbytes/sec)
3.5" Removable Hard Disks	1400	13-14	NA	$2,000	3,000
2.5" Transportable Pocket Hard Disks	80	17	NA	$650	2,200
Solid State (flash) Drives	40	0.2	$300	$800	8,000(read) 115(write)

Table 3. Removable Cartridge Drives

Media	Capacity (Mbytes)	Access Time (msec.)	Drive Cost	Media Cost	Transfer Rate (Kbytes/sec)
Floptical Drives	20	65	$500	$10	200
Bernoulli/Syquest Cartridge Drives	88	20	$550	$100	1,250
3.5 inch Magnteo-Optical Drives (EODs)	128	28-45	$1,300	$60	150
5.25 inch Magneto-Optical Drives (EODs)	650 (595 for UNIX)	35-60	$2,500 - $4,000	$120	400 (read) 200 (write)

Table 4. Tape Backup Devices

Media	Capacity (Mbytes)	Access Time (sec.)	Drive Cost	Media Cost	Transfer Rate (Kbytes/sec)
8 mm (Exabyte)	5,000	90	$3,000	$15	500
4 mm (DAT)	2,000	20	$1,400	$20	180
1/4 inch data cartridges (QIC) DC6000 format	4,000	30	$800	$50	400
Magnus data cartridge	1,300	40	$1,200	$40	600
1/2 inch 9-track tape (2400 ft. @ 6250 bpi.)	150	60	$13,000	$25	3,000
DEC TK70	296	140	$4,500	$50	
19 mm (DD-2)	25,000	30	$200,000	$25	15,000

Table 5. Consumable Media and Video Media

Media	Capacity (Mbytes)	Access Time (msec.)	Drive Cost	Media Cost	Transfer Rate (Kbytes/sec)
CD-ROM	680	300	$600	$1,500 mastering + $1.50 per copy	200 (400 expected by 1994)
WORM	400	100	$7,000	$95	1,200
CD-Recordable	630	280	$6,000	$100	
Video Laser Disk - ROM	NA	3,000	$800	$2,000 mastering + $15 per copy	NA
Video Laser Disk -WORM	NA	1,500	$8,000	$250	NA
Video Laser Disk - rewritable	NA	1,500	$20,000	$1,200	NA

SECTION 4

COMPARISON OF CANDIDATE MEDIA

In this section, we compare the candidate media identified in section 3 with respect to the requirements of CMS data distribution presented in section 2.

4.1 CAPACITY

One of the initial considerations that should be addressed is how the capacity of the various media alternatives relates to the storage requirements of CMS data. Figure 2 illustrates the capacity of each of the candidate media for storage of ADRG charts. All media alternatives can store in excess of 50 ADRG charts per media volume, exceeding the previously stated requirement of 20 ADRG charts per volume. The 8 mm tape offers the highest capacity, up to 500 ADRG charts.

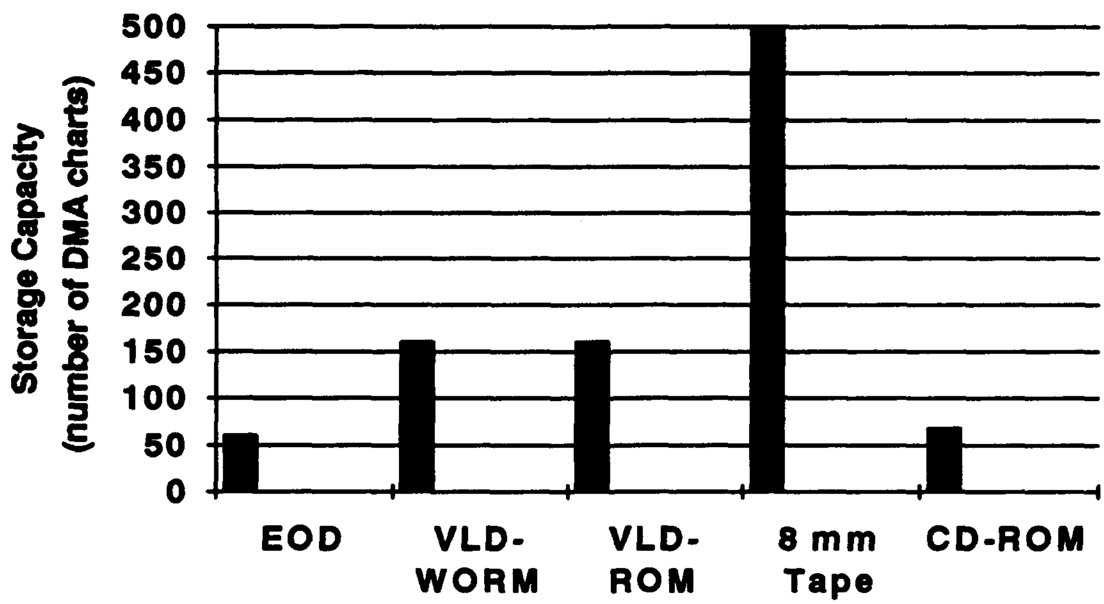

Figure 2. Media Capacity

As was discussed in section 2.4.1, image quality requirements can influence the requirements for media capacity. We described a basic CMS media requirement to store compressed CMS data and a goal of supporting multiple quality levels. Although most CMS systems will be using maps and imagery that have been compressed, other CMS systems may require uncompressed data for various reasons, including increased visual quality. Distributing uncompressed data will require significantly increased storage. Those candidate media offering the highest storage capacity are best suited to storing maps and images at multiple quality levels. The high capacity of the VLD media make them well suited to storing maps at multiple quality levels. Figure 2 capacity for VLD assumes that maps and images are stored at two quality levels: the original noncompressed ADRG pixel spacing of 254 dpi and a lower quality, spatially reduced version at 127 dpi).

Although VLDs do offer abundant capacity, the types of data that can be stored on them are limited. As we discussed in section 3.4, VLDs cannot store vector data or compressed raster data. This is a significant limitation since most CMS systems will require compressed map data and lack adequate processing capabilities to locally compress the data.

4.2 PERFORMANCE

In section 2.4.2, we identified access time and transfer rate as being the key performance factors for CMS media. We established an access time goal of 500 milliseconds and a transfer rate requirement of 400 Kbytes/sec. Each of the five candidate CMS media will meet these criteria with one exception. As we described in section 3.3, access time for the 8 mm tape can be as high as two minutes. For those CMS systems that need to use the distribution media as an on-line resource, the slow access time of 8 mm tape will be unacceptable.

4.3 PRODUCTION COSTS

As described in section 2, the CMS distribution media strategy must remain cost effective for both small and large production runs. Depending on map scales and geographic area, the production runs will vary from just a few copies to 1000 or more copies. Certain (large-scale) charts may be distributed to just a few units while other charts will be widely distributed to nearly all CMS systems. Figure 3 illustrates comparative costs for distributing a single DMA chart utilizing five media alternatives. The vertical axis shows media cost per chart in dollars, and the horizontal axis represents how many copies of a particular chart need to be distributed. This figure assumes a distribution size of 50 charts, representative of an annual update or a quick-reaction contingency distribution. We assume that the digital storage media contain CMS charts compressed at 48:1 and that the VLD media store video data at both 254 and 127 dpi to provide two levels of map quality. The costs for CD-ROM and VLD-ROM are based on quoted rates for commercial production facilities at their economy rate (8-day turnaround). CD-ROM becomes a very cost effective medium for production runs in excess of 100 copies.

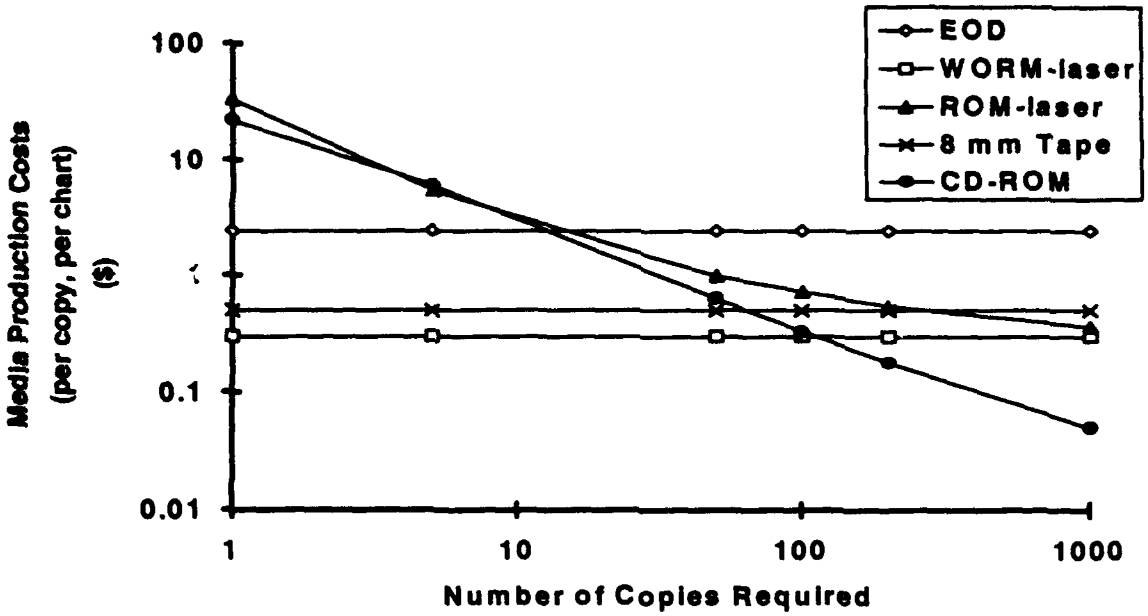

Figure 3. Media Cost per Chart versus Replication Quantity

4.4 LIFE-CYCLE COSTS

In addition to the basic media and equipment costs, the life-cycle costs of the media alternatives should be considered. In particular, rewritable media can offer a lower life-cycle cost in the long run, since the media can be reused. We need to consider how "media recycling" will affect the effective media cost of an EOD. This will permit a fair comparison between rewritable and read-only media. For example, if we assume an original media cost (*C*) and a media return rate (*x*), $\{0 \leq x \leq 1\}$ and if each media volume is returned and recycled an average (*N*) times before it fails or is lost, then the effective cost (C_{eff}) is:

$$C_{eff} \geq \frac{C}{\sum_{n=0}^{N} x^n}$$

For example, assume that 60 percent of all distributed EODs are returned to the CMS distribution center for reuse and that each EOD is recycled five times before it is lost or fails. In this case, the original cost of $120 per disk becomes an effective cost of about $50. While this is a significant cost savings, it is not a large enough change to alter our previous statements regarding the relative cost effectiveness of EOD as compared with the other candidate media. Referring to figure 2, a 60 percent reduction in media costs for EOD would drop the EOD cost per chart from $2.40 to $0.83. This would cause the break-even point between EOD and CD-ROM to move from about 10 copies to about 25 copies. CD-ROM would still offer significant cost savings for production runs in excess of 25 copies.

4.5 PRODUCTION TIME

Another important criterion is the amount of time required to create datasets for distribution. In a peacetime situation, production needs can be anticipated well in advance. In these cases, a production time of weeks, or even months, for large production runs should be acceptable. On the other hand, an unexpected deployment of forces may require rapid production of CMS datasets. Although the data needs to be produced quickly, the amount of data will be limited to that required for a specific deployment or contingency. For a conservative estimate, we assume a contingency distribution of 50 charts. Depending on mission requirements, the CMS distribution media may need to be ready for distribution in as little as 48 hours.

Figure 4 illustrates how the choice of distribution media for CMS will affect production time. Production time for media that are mass replicated (CD-ROM and VLD-ROM) is shown as a range of values from one to eight days. This is based on the practices of commercial production facilities that offer a sliding fee scale based on customer-required turnaround time. Each of the other media candidates (EOD, 8 mm tape, VLD-WORM) requires a dedicated disk/tape drive to individually create each production disk. For these media, production time is directly dependent on the number of disk/tape drives and computer resources available. Our production time calculations assume ten disk/tape drives operated continuously.

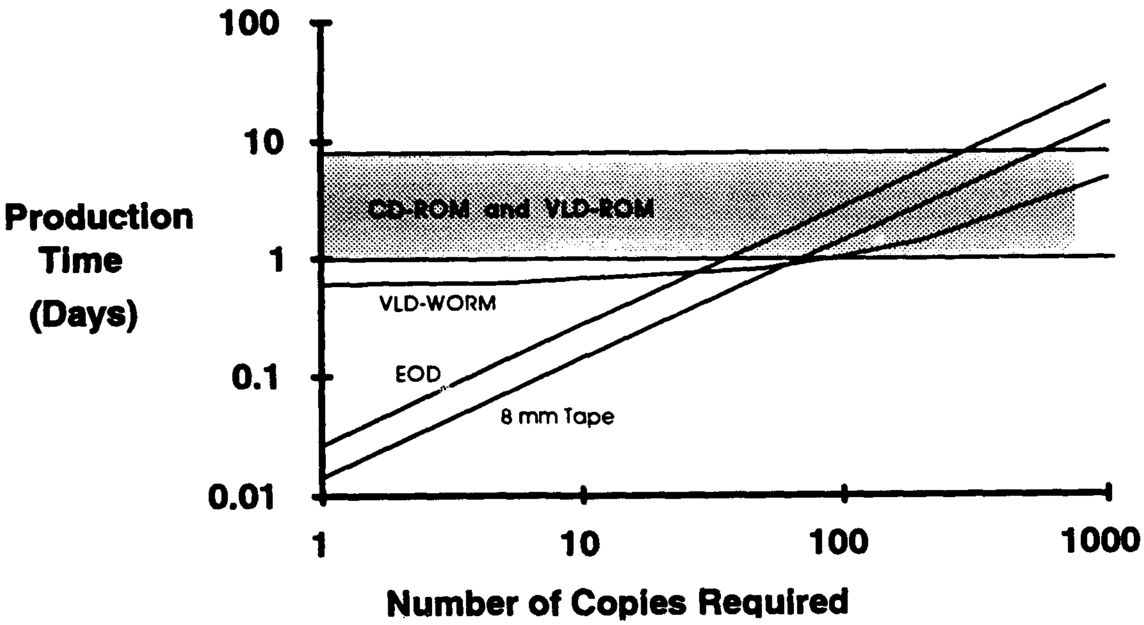

Figure 4. Production Time for a CMS distribution of 50 Charts

Both CD-ROM and VLD-ROM are well suited to large peacetime distributions, providing a production time of eight days or less with a virtually unlimited number of copies. Production time for each of the other candidate media (EOD, 8 mm tape, and VLD-WORM) are dependent on the number of copies being made. If the number of copies required is small, then EOD and 8 mm tape offer the shortest production time.

SECTION 5

A SPECIFIC EXAMPLE: AFMSS

One of the first large volume CMS users will be the Air Force Mission Support System (AFMSS). In this section, we will use AFMSS as an example to consider strategies for CMS media distribution. Although AFMSS is not yet fielded and its concept of operations is still being defined, the approximate data distribution requirements can be predicted. Based on the known size of specific map products and certain assumptions regarding AFMSS CONOPS, the size, frequency, and content of data distributions can be quantified. This section presents an overview of the AFMSS system architecture, describes the assumed CONOPS, derives the resultant AFMSS data distribution requirements, and recommends extensions to the current CMS media alternatives to serve the needs of this system.

5.1 AFMSS SYSTEM ARCHITECTURE

AFMSS is the common air mission planner for the United States Air Force and the United States Special Operations Command (USSOCOM), providing automated mission planning, materials preparation, and post-mission debriefing capabilities. AFMSS is being developed in incremental stages. The first increment to be produced in quantity (designated C1.0) is scheduled to enter production in early 1994. AFMSS consists of three subsystems: the Mission Planning Subsystem (MPS), the Portable Mission Planning Subsystem (PMPS), and the Data Preparation Subsystem (DPS).

The MPS is the basic deployable mission planning element for AFMSS, providing full capabilities and supporting up to six mission planning workstations. The PMPS provides a portable, but less capable, mission planning workstation packaged for one person portability. Computer-based mission planning is an application that is extremely data intensive. To support the planning of a variety of missions, the MPS (or PMPS) needs to have access to a vast amount of MCG&I data. The AFMSS CONOPS is expected to change considerably over the next few years.

Initially , the AFMSS DPS will assume primary responsibility for converting DMA MCG&I products into CMS products and replicating the data for distribution to AFMSS MPS and PMPS sites. Eventually, the production of most standard CMS products will be transitioned to DMA, which will send distributions of CMS data directly to AFMSS sites. As the production of standard CMS products is transitioned to DMA, the AFMSS DPS will focus on the production of nonstandard CMS products (e.g., unique maps needed by only a small number of CMS sites). The discussion that follows is based on the initial AFMSS CONOPS with the DPS being responsible for AFMSS CMS distributions.

5.2 AFMSS DPS CONCEPT OF OPERATIONS

Each DPS will be responsible for distributing datasets to a large number of mission planning sites. Each AFMSS DPS will be located at one of several Data Production Facility (DPF) sites. There will likely be a "central DPF" in CONUS, and a "distributed DPF" for each of the theaters. Most of the data exchanged between the DPF and the mission planning sites will be MCG&I data. The format for MCG&I data distributed from the DPS to mission planning sites will conform to the CMS interface standard. Nearly all of the processing required to transform source data into the CMS format will be performed by the central DPF; the distributed DPFs will be responsible for replicating and distributing data to meet the needs of individual AFMSS units.

The DPS will provide to each deployed (or recently relocated) AFMSS site an initial library of MCG&I data and subsequent periodic updates to this library. The bulk of this MCG&I library will consist of digitized charts of varying scales and digital satellite imagery. In addition, the library will also contain vector maps, terrain feature data, terrain elevation data, vertical obstruction data, and other data required for mission planning. Generally speaking, each AFMSS site will need a library consisting of two categories of data:

- Large scale, highly detailed MCG&I products covering a portion of the theater of interest, and

- Small scale, less detailed products covering the entire world.

The actual size and composition of the library will be determined by a balance between operational requirements and the media/production costs for the library.

Since many of the AFMSS sites served by a single DPS will need the same theater of interest, the DPS can probably distribute an identical library and identical updates to several of its client AFMSS sites. Such mass distributions are desirable from an economic standpoint since mass replication can drastically reduce distribution costs for certain media. In addition, mass distributions will simplify configuration control for the multiple CMS libraries that the DPS will need to maintain.

Although the exact number of AFMSS sites to be supported by a single DPS is dependent on the number of planning systems deployed per theater, we will assume 200 CMS sites per DPS. This assumption is in line with the expected number of AFMSS MPSs and PMPSs to be deployed.

5.3 SIZE AND FREQUENCY OF DPS DATA DISTRIBUTIONS

Each DPS will be responsible for distributing and maintaining some 200 CMS theater-specific libraries located at the client CMS sites. Much of the data maintained at these sites will be identical, particularly the small-scale worldwide charts. The size of the CMS libraries will be determined by a compromise between operational requirements and media/production costs. The AFMSS DPS has been sized to produce CMS libraries that will provide complete coverage of all MCG&I products for an area comparable to a Global Navigation Chart (GNC). Such a distribution is unreasonably large, and each site will only use a small portion of the low-level charts and imagery.

Table 6 shows how the various categories of CMS data may contribute to the total size of each CMS library. In the left-most column, we have grouped the CMS products into five categories (Global, Regional, Area, Standard Local, and Optional Local). For each of these CMS data categories, the second column lists several options with regard to the amount of geographic coverage that might be maintained at AFMSS sites. The geographic coverages listed relate to DMA chart coverage—figure 1 shows the relative geographic coverages of several DMA charts. The right-most two columns of table 7 quantify the data storage requirements for CMS compressed data in both megabytes and the number of EODs required. For example, Standard and Optional Local products for a geographic area equivalent to a JNC chart would require 80 EODs (30+50), while Area products for a similar geographic area would easily fit on a single EOD. This table singles out EOD media, because the current AFMSS baseline assumes that EODs will be used for CMS distributions.

Table 6. Breakdown of CMS Library for AFMSS

Data Category	Options for Geographic Coverage	Size in Gbytes	Number of EODs
Global GNCs, JNCs, WVS	entire world	1.7	3
Regional DCW (VMap level 0)	entire world GNC-sized area	2.5 0.2	4 1
Area ONCs and TPCs	GNC-sized area JNC-sized area	0.9 0.2	2 1
Standard Local ADRI, DTED 1, DFAD 1, JOG-A, PVOD	GNC-sized area JNC-sized area ONC-sized area	92.1 17.5 4.4	154 30 8
Optional Local DTED 2, JOG-G, ATC, TLM	GNC-sized area JNC-sized area ONC-sized area	154 29.2 7.3	250 50 13

The DPS will distribute a CMS library containing some combination of products and coverages. The size of each CMS library will be determined primarily by operational requirements. Once the library has been established and assuming that operational requirements do not change, the libraries can be maintained by distributing updates to each site. Annual update distributions for each CMS library are expected to be about 20 percent of each maintained CMS library. Table 7 characterizes two extremes for AFMSS CMS library size. Using different operational requirements, we identify a large "worst-case library" and a smaller "contingency library." The table also shows the expected size of update distributions based on these library sizes and updates of 20 percent per year.

Table 7. Size Estimates for AFMSS CMS Distributions

	Size of AFMSS Distributions (Gbytes)		
Data Category	**Worst-Case Library**	**Contingency Library**	**Annual Update**
Global	1.7	1.7	0.3
Regional	0.6	0.2	0.0 - 0.1
Area	0.6	0.2	0.0 - 0.1
Standard Locals	54	18	3.6 - 10.8
Optional Locals	87	0	0 - 17.4
TOTAL	**143.7 Gbytes**	**20.1 Gbytes**	**4 - 29 Gbytes**

Each site will probably receive worldwide coverage for a limited number of high-level MCG&I products. If we assume worldwide coverage of GNC, JNC, and WVS products, this will require CMS media capable of storing 1.7 Gbytes. The distribution media containing these products would be prime candidates for mass replication, since every CMS site would receive an identical set of media. Using EOD as an example, these high-level, worldwide products could be stored on three EODs.

In addition to these high-level products, each site will receive low-level coverage (e.g., DTED, DFAD, TPC, TLM, ADRI, etc.) for selected areas of interest. For example, the distributed CMS library may contain detailed local products for:

- Bases and locations frequently traveled to
- Test ranges, exercise locations, etc.
- "Hot spots" where future military actions are possible

The amount of such low-level coverage distributed to and maintained by each site will be influenced by operational requirements, data availability, and media/production costs. For example, in a contingency situation, low-level coverage for a single JNC-sized area might be required. If we assume that only standard local products are required for this area, then the total CMS library size about 20 Gbytes of data. This "contingency library" may also meet the peacetime requirements for those CMS sites with modest data requirements.

Other CMS sites may require a larger CMS library. As a worst case, units that routinely travel or perform exercises in several different locations may require two or three different JNC-sized coverage areas. A complete distribution of this size, including both standard and optional local products, would require about 144 Gbytes of data. Note that in most cases, each AFMSS site will already have an established CMS library covering its area of interest, so only an update will be required. We assume a compression ratio of 48:1 for raster maps and 4:1 for imagery.

Note that these estimates are based only on MCG&I products expected to be required and available at the time of AFMSS deployment (1994). The availability of, or requirement for, additional highly detailed products, such as DFAD 2, DFAD 3C, or multispectral imagery, may further increase the distributed CMS library size.

5.4 AFMSS MEDIA REQUIREMENTS

In this section we discuss CMS distribution media requirements for AFMSS and relate them to the generic requirements identified in section 2.3, as well as the media comparisons presented in section 4.

5.4.1 Capacity

To insure compliance with the AFMSS download performance requirements and reduce the amount of user interactions (i.e., swapping of disks or tapes), it is desirable to have each distributed CMS media volume contain as much data as possible. On the other hand, the size and weight of each CMS media library must be kept as small as possible—particularly for the PMPS. In this way, the AFMSS capacity requirements are consistent with the generic CMS media capacity requirements discussed in section 2.3.1.

Also discussed in section 3.2.1 is the requirement that the CMS distribution media be capable of storing data in the compressed CMS format. Most CMS systems will be exchanging CMS data in this compressed format. This is an especially critical requirement for both the AFMSS MPS and PMPS, because these AFMSS subsystems must download compressed CMS data to aircraft data transfer devices (DTDs). The downloaded data will be used by the avionics and moving map systems on-board the aircraft. The performance and storage requirements of these systems require that the data exported from AFMSS be in a compressed format. Since AFMSS lacks adequate processing resources to compress the data locally, this means that the CMS distribution media must contain compressed data. Based on these considerations, a distribution strategy based on video disks is not appropriate for AFMSS requirements. The video disk cannot store compressed data, which both the MPS and PMPS need.

5.4.2 Performance

For AFMSS, the CMS distribution media will be used by the MPS and PMPS in different ways. The MPS will only use the media as an archive for downloading data onto the internal hard drives. Based on the available hard drive capacity and the amount of geographic data that each MPS must have available on-line, the ADRG data must be compressed by at least 48:1. For AFMSS to meet its performance requirements for "cold start," the CMS media must contain data that is already compressed, and the distribution media must support a transfer rate of at least 400 Kbytes per second. Data downloading will happen only infrequently on the MPS, so media access time is not a critical performance driver for the MPS.

Access time is critical for the PMPS, which may need to utilize the CMS distribution media as an on-line resource. This is because the PMPS will have limited internal hard drive capacity. For this reason, a CMS library based on 8 mm tape is not acceptable for the PMPS. This means that although 8 mm tape has been shown to offer significant cost savings for some distributions, it is not a viable solution for AFMSS PMPS systems.

5.4.3 Production Costs

Based on the candidate media alternatives discussed in section 3, we can identify how different media strategies will impact production cost for AFMSS. Table 8 shows the media costs for each of the 5 different categories of CMS data. The media costs for Global CMS products (GNC, JNC, and WVS) are based on 1000 fielded AFMSS systems with each system receiving a copy. Because each of the other data categories contain increasingly detailed CMS products, the costs assume an appropriate decrease in the number of copies required. That is, for those specific map products that are more detailed and cover a smaller area, fewer copies will generally be required. This is an important consideration for the mass production media (i.e., CD-ROM and VLD-ROM) because it illustrates how unit production cost is dependent on the number of copies being produced.

In order to calculate total costs for a particular mix of distributed products (i.e., "worst-case" and "contingency" distributions), the costs shown in table 8 must be adjusted to reflect the type and number of products being distributed. Table 8 provides multiplier factors that can be used to adjust the cost values for either "worst-case" or "contingency" distributions. The costs for Global products apply to both of these distributions, since both include worldwide coverage of these products. The costs for Regional, Area, and Standard Local products are based on the "contingency" distribution. To determine costs for the "worst-case" distribution that provides three times the coverage for these products, each of the costs should be multiplied by a factor of 3. The costs for Optional Local products are based on coverage of a single JNC-sized area; the worst-case distribution provides three times this coverage but the contingency distribution does not include any of these optional products.

Table 8. Media Production Costs for AFMSS CMS Distributions by Data Category

	CMS Data Category				
	Global	**Regional**	**Area**	**Standard Locals**	**Optional Locals**
Geographic Coverage	worldwide	GNC-sized area	JNC-sized area	JNC-sized area	JNC-sized area
Assumed Production Size	1000	50	20	5	1
Cost multiplier for Contingency dist.	1	1	1	1	0
Cost multiplier for Worst-Case dist.	1	3	3	3	3
Media Production Costs for Each Data Category for Each Fielded AFMSS					
CD-ROM	$9	$5	$153	$8100	$67,500
EOD	$360	$120	$240	$3600	$5880
8 mm Tape	$20	$20	$20	$80	$120
VLD-WORM	$250	$250	$250	$2500	$37,500
VLD-ROM	$24	$90	$250	$1750	$52,500

Overall, 8 mm tape offers the lowest media cost, except for Global Data where the large production run makes CD-ROM more cost effective. Even for the smaller production runs of Regional and Area data, CD-ROM can offer AFMSS significantly lower cost than the current EOD baseline. Note, however, that for the very small production runs of Local data, the high mastering costs of CD-ROM becomes prohibitive. The VLD media do not offer cost savings competitive with either CD-ROM or 8 mm tape.

5.4.4 Production Time

Similar to the generic production time requirements discussed in section 2.4.4, AFMSS must also support small "quick-reaction" distributions as well as larger peacetime distributions. The quick-reaction distributions will consist primarily of Local datasets and may need to be produced in 48 hours or less. As we illustrated in section 4.5, the EOD and 8 mm tape media are best suited to supporting small, quick distributions when only a limited number of copies are required.

The larger, predictable AFMSS peacetime distributions will encompass all five data categories, but production times of up to 1 month may be acceptable. Although production time will not be a critical factor for these AFMSS distributions, we have shown that mass production media (i.e., CD-ROM and VLD-ROM) will offer the shortest production time if the production run is sufficiently large.

5.5 RECOMMENDATIONS FOR AFMSS

Based on system requirements, we have eliminated the 8 mm tape and VLD from consideration as the CMS distribution media for AFMSS. Our attention is focused on CD-ROM and EOD media. As illustrated in table 8, CD-ROM offers significant cost savings for large production runs; but the EOD provides shorter production time and reduced cost when the production run is very small. As discussed in section 4.2, the break-even point between EOD and CD-ROM occurs when production runs exceed 10-25 copies. For AFMSS, this means that CD-ROM will offer significant savings for the distribution of Global and Regional and possibly Area data distributions. EOD will remain cost effective for local distributions. This dual media strategy based on CD-ROM and EOD media will offer the potential for significant cost savings, as compared with the current EOD-only strategy. The media recommendations derived for AFMSS will remain valid even when the production of CMS products is transitioned to DMA.

SECTION 6

CONCLUSION

In order to share data and data production costs between CMS systems, a coherent CMS media strategy based on a limited set of "standard" media types is desirable. Based on a generic set of requirements, we have identified and investigated several candidate media for CMS distributions. After comparing the media across a wide range of production scenarios, we recommend a dual-media solution based on CD-ROM and EOD. This media strategy offers a cost-effective solution that will meet the requirements of many CMS systems. Using AFMSS as an example, we have illustrated the significant cost-savings potential of this strategy as compared to the current EOD-only strategy. Although CMS systems with unique requirements may require unique media solutions, we encourage those systems with requirements similar to AFMSS to adopt this dual-media strategy.

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GLOSSARY

ADRG	Arc Digitized Raster Graphics
ADRI	Arc Digitized Raster Imagery
AFMSS	Air Force Mission Support System
CAV	constant angular velocity
CD-R	Compact Disk Recordable
CD-ROM	Compact Disk Read Only Memory
CD-WO	Compact Disk Write Once
CLV	Constant Linear Velocity
CMS	Common Mapping System
CONOPS	Concept of Operations
DAT	Digital Audio Tape
DCW	Digital Chart of the World
DFAD	Digital Feature Analysis Data
DMA	Defense Mapping Agency
DPF	Data Production Facility
DPS	Data Preparation Subsystem
DTD	Data Transfer Device
EOD	Erasable Optical Disk
GNC	Global Navigation Chart
ICD	Interface Control Document
ISO	International Standards Organization
JNC	Jet Navigation Chart
MCG&I	Mapping, Charting, Geodesy, and Imagery
MO	Magneto Optical
MPS	Mission Planning Subsystem
NTSC	National Television System Committee
PMPS	Portable Mission Planning Subsystem
QIC	Quarter Inch Cartridge
SCSI	Small Computer Systems Interconnect
USSOCOM	United States Special Operations Command
VLD	Video Laser Disk
WORM	Write Once Read Many
WVS	World Vector Shoreline