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The application of computers and computer assisted techniques to support current and future (thru 1988) requirements for chart production at the Defense Mapping Agency Aerospace Center (DMAAC) is discussed. Topics discussed include: Digital Paneling (computer assisted technique for reducing large scale map source to a smaller scale control projection); computer assisted chart symbolization for chart products, Digital Landmass System (DLMS), a data base containing Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD) to (cont)

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support charting requirements and the computer generation of relief information from DTED data. Control, data collection, editing, chart compilation, chart revision, color separation, symbolization, and printing can be enhanced or accomplished by automated processes. Also considered is the development and continual evaluation of a Digital Cartographic Applications Data Base (DCAD) to provide this Center with a capability to support advanced digital mapping requirements. The DTED and DFAD data currently produced by DMAAC are used to support advanced aircraft simulators and navigation systems requirements.

OVERVIEW OF AUTOMATED CARTOGRAPHY EFFORTS AT DMAAC

SUMMARY

Transition from the traditional (manual) color separation of chart products to an automated process is being accomplished at the Defense Mapping Agency Aerospace Center (DMAAC). The Automated Graphic Digitizing System (AGDS) has been the primary instrument for converting source graphics into a digital format. The AGDS also provides the cartographer with a capability to interactively manipulate (edit, transform, etc.) the collected chart feature data into color separated, tagged digital files. The tagged color separated files are processed through off-line Graphic Line Symbolization Software (GLSS) into plot files for the subsequent generation of symbolized color separated positives in a photo finishing plotter.

Digital Feature Analysis Data (DFAD) specifications are being upgraded to support automated charting. The upgraded specifications are known as second edition. Special emphasis is being placed upon the collection of roads, railroads, cultural features, drainage, and attribute data required to support effective automated charting production processes. The second edition requirements are for all DFAD collections. Second edition DFAD data is to be included in a Digital Cartographic Applications Data Base (DCAD) and would be stored in a line segment noded data format for economy of storage and ease of maintenance.

Softcopy production requirements through the decade of the 80s is discussed. An all-digital softcopy production process interfaced with DCAD through a DMA standard interchange format is presented. The final symbolization software would be modified versions of GLSS. The DCAD data base will be queried for digital data to produce color separations for contours, drainage, roads, railroads, etc. The cartographer should have the capability to output separations to a laser plate maker (LPM) for lithographic printing or to composite all separations for the direct printing process (raster color printing techniques).

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OVERVIEW OF AUTOMATED CARTOGRAPHY EFFORTS AT DMAAC

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ABSTRACT

The application of computers and computer assisted techniques to support current and future (thru 1988) requirements for chart production at The Defense Mapping Agency Aerospace Center (DMAAC) is discussed. Topics discussed include: Digital Paneling (computer assisted technique for reducing large scale map source to a smaller scale control projection); computer assisted chart symbolization for chart products, Digital Landmass System (DLMS), a data base containing Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD) to support charting requirements and the computer generation of relief information from DTED data. Control, data collection, editing, chart compilation, chart revision, color separation, symbolization, and printing can be enhanced or accomplished by automated processes. Also considered is the development and continual evaluation of a Digital Cartographic Applications Data Base (DCAD) to provide this center with a capability to support advanced digital mapping requirements. The DTED and DFAD data currently produced by DMAAC are used to support advanced aircraft simulators and navigation systems requirements.

INTRODUCTION

The Defense Mapping Agency Aerospace Center (DMAAC) has the responsibility to meet an ever increasing number of different Mapping Charting and Geodesy MC&G requirements. The charting program primarily consists of the Series 200 (S/200) and the Navigation and Planning (NAV/PLAN) Charts. Special charts are produced for NASA, Air Weather Service and many other users. Most of these charts and navigation products are produced using traditional cartographic methods'. The traditional chart production process (i.e., feature selection, paneling, compilation, symbolization, negative engraving, etc.) requires manual, labor intensive skills. Therefore, a significant portion of DMAAC's production resources are devoted to assuring that these products are kept current with user's needs. Obsolescence comes from either or both of the following reasons: The charts no longer meet current accuracy requirements; and the information provided is outdated. Thus, DMAAC has established a need for accurate up-to-date cartographic information in a digital format readily transformed to meet specific charting requirements. Specifically, DMAAC has the requirement for a Digital Color Separation Production Process to include the collection, maintenance and exploitation of a data base of product independent digital cartographic information. The data base must contain not only lineal features in a line segment noded digital format, but also sufficient textual information to support utilization requirements for a "Family of Charts" (FOC) production process. This paper discusses DMAAC's current, proposed and future efforts for automating chart production processes to include the development and implementation of a Digital Cartographic Applications Data (DCAD) base for chart features in a standard linear format (SLF).

TRADITIONAL COLOR SEPARATION

The traditional color separation techniques for chart production require manual paneling, compilation and negative engraving. These manual, labor-intensive processes

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are prime candidates for computer assisted color separation techniques. The Domestic Series 200 program was selected as the first candidate for automated color separation at DMAAC because of the large number of charts produced each year. S/200 charts are produced at a scale of 1:200,000 and are used by air crews for general planning, in-flight navigation and training. After collecting the cartographic source package, the cartographer begins highlighting, on USGS 7-1/2" quadrangle sheets, those planimetric and hypsographic features selected for portrayal on the 1:200,000 scale chart. The cartographer performs a sheet to sheet match and the highlighted cartographic source is then scaled against the projection and photographically reduced to 1:125,000 scale. The film positive photo reductions are paneled to the 1:125,000 scale projection. This serves as a panel base from which final planimetric, hypsographic and special feature manuscripts (i.e., Contour Drainage, Roadroad, culture, etc.) are drafted. The manuscripts are drafted at 1:125,000 compilation scale, then photo reduced to the final 1:200,000 chart scale and imaged on scribe cote. The negative engraver then color separates and symbolizes the various chart features manually on the scribe cote. The engraved scribe cote (color separate) is used for making the lithographic printing plate[2].

<u>Objectives for Automating the Traditional color Separation Processes</u> - The objectives for automating the traditional color separation processes are: (1) To improve existing production processes, (2) Standardization, (3) Quick response to users needs, (4) Cost Savings (Maintenance), and (5) Movement toward an all digital, softcopy production system. The aim is to improve existing production processes through automation, to develop and implement a Digital Cartographic Applications Data Base (DCAD), and to implement an all digital softcopy production system by the mid to late 1980's.

CURRENT DIGITAL PROGRAMS

DMAAC is producing prototype charts from digital data. The digital data for these charts are collected, edited, and color separated in-house by the Automated Graphic Digitizing System (AGDS). The current digital color separation production scenario at DMAAC is shown in Figure 1. The AGDS collects line center data and generates line segments which are "tagged" by the operator with an appropriate Graphics Line Symbolization System (GLSS) code. The cartographic features from the digital data are symbolized according to chart specifications and plotting instructions for them are generated off-line by the GLSS software. Application of the GLSS software can save 50% of the man-hours normally used by the negative engraver for building lithographic color separation plates. Tagged digital data from the AGDS is archived for later chart revisions.

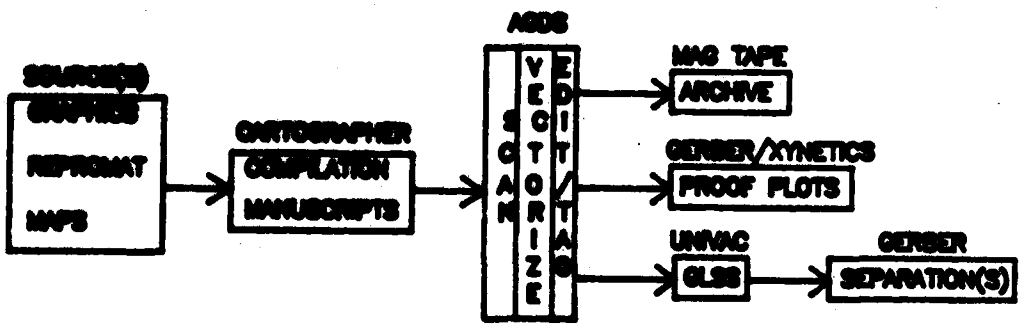


Figure 1. Digital Color Separation

Automated Graphic Digitizing System - The AGDS system is designed for data collection, interactive editing, and color separation of compilation overlays or selected feature lifts. The three main subsystems of the AGDS system are: the scanner, the vectorizer, and the edit/tag (Figure 1) subsystem. The laser scanning subsystem is used to scan compilation overlays outputting the data in raster format. The vectorizing subsystem converts the raster data to vector format. Once the scanned overlays are in vector format, the data are input to the edit/tag subsystem. The cartographer at the edit/tag subsystem has the capability to interactively edit the data, create sub files from the data (i.e., select feature lifts, compilation overlays, etc.), and to mathematically transform the separate overlays to the compilation projection base (Digital Paneling). Common points between the individual overlays and projection base are used for controlling the overlays to the projection and the cartographer can digitally transform the overlays to the projection. He then interactively inserts unique feature identification codes (FIC) to features according to their unique color separation. For example, drainage would be displayed on the blue color separation whereas cultural features would be displayed on the black separation. The color separations correspond to the colors for the lithographic printing plate. The FIC, or tag number corresponds to a specific set of previously defined instructions for feature symbolization. Table 1 is an example of the procedures and symbol pieces required to symbolize a non-perennial drain[4].

Table 1. Symbol Specification File

Feature Identification Code	Conformal Non-Conformal	Type of Symbol	Lineal (blank) Flash(F)	Symbol Size (inches)	Symbol Line Weight (inches)
4347	CON	DASH		.193	.007
	CON	SPACE		.029	.000
	CON	DOT	F	.007	.007
	CON	SPACE		.025	.000
	CON	DOT	F	.007	.007
	CON	SPACE		.025	.000
	CON	DOT	F	.007	.007
	CON	SPACE		.029	.000

After the data has been color separated at the edit/tag subsystem, an output tape is generated for off line chart symbolization by the GLSS software.

Graphic Line Symbolization System - The GLSS software is to provide the cartographer with a chart that shows cartographic features, such that one feature can be easily distinguished from the other. The GLSS software converts line centered data to a specific product format which depends upon the chart specifications being used for the final chart compilation. The product format is generated by a graphic film (photo) plotter[4].

Film Positive Separates From GLSS - To this point, the collection and processing of digital cartographic data through AGDS and GLSS systems have been discussed. Now let's view a composited subplot taken from a full scale production chart. Figure 2 presents a symbolized plot for the following color separations: contours, drainage, roads, railroads, and radar significant analysis code (RSAC). Each separation encompasses the same geographic area. The cartographic features for each separation are plotted according to chart specifications. Figure 2 shows a composite registration of the film positives.

Figure 2. Composite of Separations

The symbolized film positives from GLSS eliminate the need for the negative engraver to extensively hand engrave symbology on scribe cote. The engraved scribe cote is used for making photo negatives for creating a lithographic press plate[4].

Savings For the Negative Engraver - By eliminating the need to manually engrave most chart symbology, the negative engraver can save 60% of the manhours he would need to engrave the chart. For a particular prototype production chart, the engraver time required to scribe symbology and prepare the chart for printing was 430 manhours. To color separate the same prototype chart using digital data and GLSS software for symbolization required only 170 manhours from the negative engraver. Additional savings would be made for smaller scale, larger format charts.

Digital Landmass System (DLMS) - DMAAC is currently producing digital files of Feature Analysis Data (DFAD) and Digital Terrain Elevation Data (DTED). These digital files are combined to form the Digital Landmass System (DLMS) and are used to support advanced aircraft simulators and navigation system. The DLMS data base contains two major types of data, elevation data and physical feature data.

DTED - Elevation data is collected by either automatically scanning profiles from a photogrammetric model on an analytical stereo plotter or by digitizing contours (AGDS) from an existing map. Photogrammetric methods are used to collect the majority of DTED compiled for the DLMS in DMA. Interpolation of collected elevation data yields a uniformly spaced grid of elevations in accordance with DLMS specifications for DTED.

Cartometric methods for DTED production are based on AGDS collection of map/chart contour manuscripts. Similar to photogrammetric methods, interpolation algorithms for converting vectorized raster contour data to final DTED matrix form are based on weighted radial averaging methods for points surrounding matrix posts. Contour data is likewise enhanced with geomorphic information (e.g., stream beds, ridges, etc.) to preserve the integrity of terrain forms. Collected data is then transformed, via post processing on the UNIVAC 1100 Series computer to the DTED matrix format.

The role of Digital Cartography is increasing at DMAAC. In areas where a suitable data base exists, contours are generated from Digital Terrain Elevation Data (DTED). Cartographers use a computer program which generates contours from a rectangular array of elevation points at specified increments of latitude and longitude. A smoothing algorithm automatically eliminates noise and bias errors which enter in the collection process. Generalizing [illegible] retains the geomorphic character of the surface while thinning the elevation data for compilation at smaller scales. Finally, the contouring algorithm converts the elevation matrix data to linear contours. The advantages of computer drawn contours are [illegible] (1) [illegible] hours are reduced, (2) we are able to take advantage of the [illegible] data base, and (3) there is less requirement for cartographic interpretation of topography.

DFAD - The associated feature data file holds digitally encoded descriptions of culture and landscape features within the terrain region. Most feature types are represented by polygonal boundaries and descriptor tables. The table includes coded information such as surface type (e.g., forest), predominant makeup (e.g., deciduous trees), and average height. Linear features such as bridges, dams, walls, and pipelines are specified by line segments, while others, such as towers and certain buildings are specified as point locations with feature heights included. Header records containing index and reference information are used to relate descriptive information to corresponding geographic locations of features. Detailed DLMS data content is described in reference 6, "Product Specifications for Digital Landmass System (DLMS) Data Base."

DFAD Specification Upgrade for Charting Requirements - The DFAD specifications are being updated to support charting requirements. The scale at which these data are collected must be sufficiently large so that it will support all charting products. Special emphasis must be placed on the collection of roads, railroads, cultural features, and drainage. Attribute data for features of the DFAD data base must be of such detail to insure successful retrieval for charting.

Advanced Edit System (AES) - The AES in Figure 3, was developed as an interactive editing system for editing symbolized color separation data in final plotter format prior to final plotting. The AES can also be used for editing digital features from various other sources. It is anticipated that DCAD data will be edited on the AES system for revision, and compilation of the 200,000 scale aeronautical charts.

PROPOSED AND FUTURE DIGITAL PROGRAMS

Softcopy Production - DMAAC is escalating the automation of the charting process and expects to achieve an all digital softcopy production capability by 1988 (Figure 3) to include the establishment, as appropriate, of uniform procedures relating to the collection, screening, evaluation, editing, symbolization, retrieval and exchange of digital source and production data. It is anticipated that the concept of digital color separation and data base development will necessitate some minor changes in product specifications and compilation procedures. Existing charting specifications for DMA products were developed in an era devoid of automation. These specifications need to be reevaluated for redefinition of certain cartographic rules to maximize the savings that are possible through automation while maintaining effective communication to the users[3].

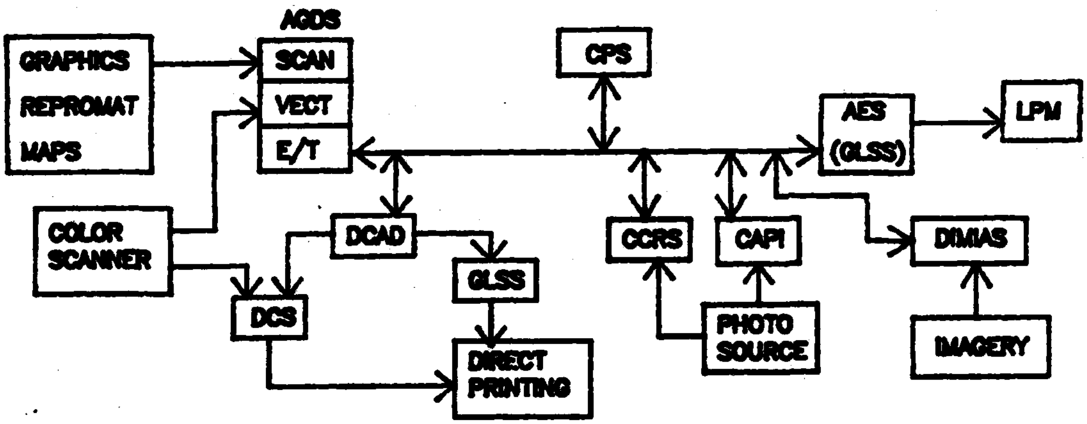


Figure 3. Proposed Production Scenario

Table 2 lists currently identified developmental efforts to support this proposed softcopy production system.

Table 2. Developmental/Efforts to Support Softcopy Production[3].

I System Capabilities

- Advanced Edit System (AES) to support preparation, editing and plotting of symbolized digital map color separation data.
- Cartographic Compilation/Revision System (CCRS) to provide a capability to simultaneously work with graphic, photographic and digital data.
- Clustered Carto Processing System (CPS) will provide a set of interrelated automatic and interactive functions to accept digital data from AGDS, CAPI, DIMIAS, and perform various transformations on the data.
- Computer Assisted Photographic Interpretation System (CAPI) for integrated photo interpretation/mensuration/compilation to support DTED, DFAD, Digital Vertical Obstruction Data (DVOD) and automated charting.
- Digital Interactive Multi-Image Analysis System (DIMIAS) is used primarily to analyze and extract landscape features from digital imagery in a semi-automated mode.
- Digital Chart System (DCS) to be a new generation of auto carto hardware/software to accomplish maximum exploitation of the planned Digital Cartographic Applications Data (DCAD) base.

II Support Hardware

- Color Scanner for rapid digitization and separation (by color) of symbolized cartographic feature data portrayed in DMA chart and source materials in multi-color lithographic format.

- Digital Laser Platemaker to provide a capability to go directly from digital data to pressplate.
- Direct Printing to combine text and digital color separation data and directly print in a variety of colors in a single press run with no reproduction copy or plate preparation.

III Data Base

- Digital Terrain Elevation Data (DTED) is a digital file which is a subset of the Digital Landmass System (DLMS). DTED is composed of terrain data with elevations stored in a matrix referenced to mean sea level, with horizontal positioning referenced to the World Geodetic System (WGS-72).
- Digital Feature Analysis Data (DFAD) is a digital file which is a subset of the DLMS system. It described the physical characteristics of the three -dimensional surface described by the DTED.
- Digital Vertical Obstruction (DVOD) is a digital file consisting of vertical obstructions referenced to WGS-72.
- Digital Cartographic Applications Data Base (DCAD) is a data base of chart features in a standard lineal or segment-noded format (SLF)). DCAD is a combined product specification which will satisfy DFAD, DTED, DVOD and automated charting requirements.

IV Support Software

- Software for Auto Carto to provide advanced contours to matrix.
- Matrix to contour and line data thinning.
- Auto Carto Feature ID to support product compilation i.e. automatic tagging of cartographic features.
- Line generalization for automatic adjustment of chart detail for product scale changes.
- Universal transformations and adjustments.

Data Base Requirement - Regardless of the complexity of the above mentioned production processes, the creation of an off-line Digital Cartographic Applications Data Base remains as one of the largest hurdles to be overcome prior to implementation of an effective Automated Charting production process. The many systems within the proposed production process of Fig. 3 would currently be limited in their effectiveness for lack of a common standard format which would allow data exchange between those systems not directly interfaced. DMA is developing such a Standard Linear Format (SLF) for efficient interchange of digital data. Such a format could be the logical basis for DCAD, and for this paper, DCAD and SLF will be synonymous[3].

In the past, the charting, DTED, DFAD and DVOD programs have been separate and legitimate programs because each had its own requirement and production schedule[3]. Typically though, DMAAC requirements for charting, DFAD, DTED and DVOD could all be derived from the same basic control and source materials. The CAPI system is expected to provide this capability to achieve all four requirements in a single pass. It would produce common data elements, to the extent practical, in terms of cost and time available, when digital data is required to support multiple products over the same geographic area. Such a production process would capitalize on redundant production requirements, provide source and product commonality and subsequently minimize proliferation of production and maintenance software. DCAD has two basic design objectives: 1) To store a string of data only once, no matter how many features it may be a part of (segment/node format)., 2) To accommodate multi-product and multi-series charting requirements[3].

The segment node format of DCAD will have inherent advantages over the polygon (enclosed figure) format currently used for DFAD data storage. The polygon format does not identify nodes of feature segments. The whole feature (Fig. 4) can be identified only as a segment. Thus, DFAD features sharing a common boundary were overlapped to insure coverage. This procedure was developed because, at that time, only manual digitizers were available for data collection and the capability to digitize a single common boundary for adjacent features was impractical. Manual overlap could be eliminated in off-line post processing of the digital data but often resulted in the subsequent computer generation of overlap slivers or fictitious gaps in the digital data and additional processing was required to eliminate them, where possible. The line segment noded format would eliminate this problem, avoid double storage or common boundaries, simplify update and correction, and be responsive to thinning and generalization algorithms.

It is feasible to develop a storage format designed to accommodate these requirements. Such a design would include the following[3].

1. Header information to contain descriptive information or attributes of the data set.

2. Data sets to accommodate feature and line segment information.

a. Feature information (Table 3) identifies the unique features which make up the data set. Specifics on feature data content would depend upon the product specification .

b. Line segment information (Table 3) contains the actual coordinate strings for the segments which make up each unique feature. All features which include a segment would be so identified.

3. Free text information to further define or uniquely qualify data as required.

POLYGON | LINE SEGMENT

FEATURE A: SEGMENT 1
FEATURE B: SEGMENT 2
FEATURE C: SEGMENT 3

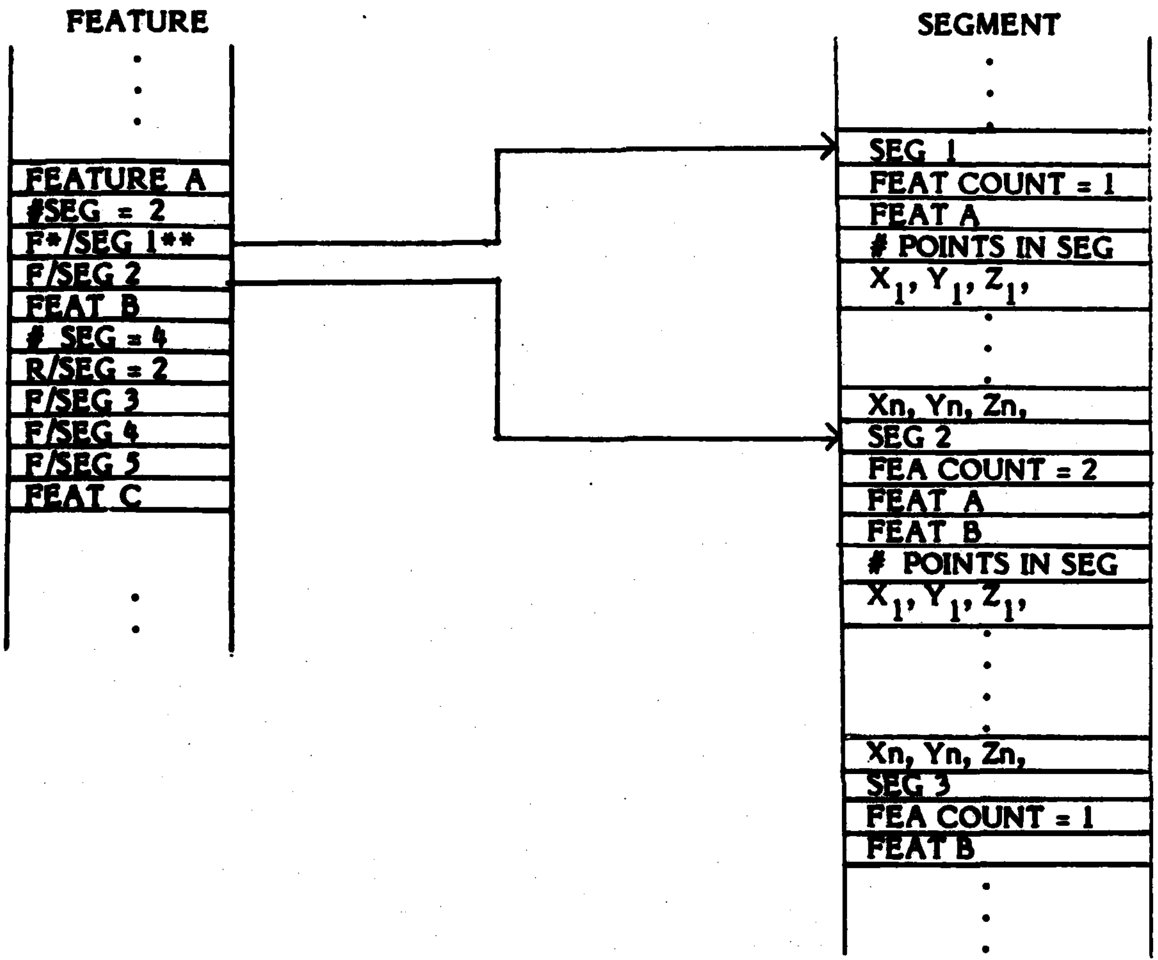
A

FEATURE A: SEGMENTS 1, 2
FEATURE B: SEGMENTS 2, 3, 4, 5
FEATURE C: SEGMENTS 4, 6

B

Figure 4 Data Base Formats

Table 3. Line Segment Data Sets



* Direction of segment (Forward (F) on Reverse (R)).

** Segment list is ordered to track the feature boundary.

CONCLUSION

Automated Charting at DMAAC is approaching production status. Equipment and systems projected to support future auto carto production requirements, through the decade of the eighties, have been defined and are in development. To support these future requirements, DMAAC is developing for implementation a Digital Cartographic Applications Data (DCAD) base to support charting requirements where digital data is available. Relief information would be generated from DTED source; chart feature data would be derived from DCAD.

To satisfy charting requirements using DCAD as source, additional software development is needed. Algorithms are being investigated and will be developed to support the filtering, generalization, displacement and symbolization requirements of multi-series, multi-scale charting. The cartographer should also have the option to output the final color separations to a laser plater maker for lithographic printing or to exercise a computer algorithm which will composite all separations for the direct printing process (raster color printing technique). For the immediate time frame, digital cartographic data for input to DCAD must be collected using various collection equipments and sources. Computer systems, software, and procedures such as: Digital Paneling, AGDS, GLSS, Gerber/Xynetics Proof plotting, and Gerber photo plotting will be the current main stays for automated charting.

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