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The implementation of digital moving map systems (DMS) aboard tactical naval aircraft has resulted in a dramatic shift from the use of paper charts to digital chart products for naval mission planning and navigation. A DMS computer stores all of the digital maps that are required for a particular mission and displays up-to-date threats, intelligence, or other information as pilot-selected overlays to the base chart. An effective DMS provides pilots with precise, hands-off route selection and navigation information (Fig. 8). The DMS that is currently used on AV-8B Harriers and F/A-18 Hornets was originally designed for night-attack air missions, since the system provides valuable positional information when visual flight navigation is limited. In direct support of these navigation and mission planning systems, the Naval Research Laboratory-Stennis Space Center (NRL-SSC) is developing the Compressed Aeronautical Chart (CAC) database [1].

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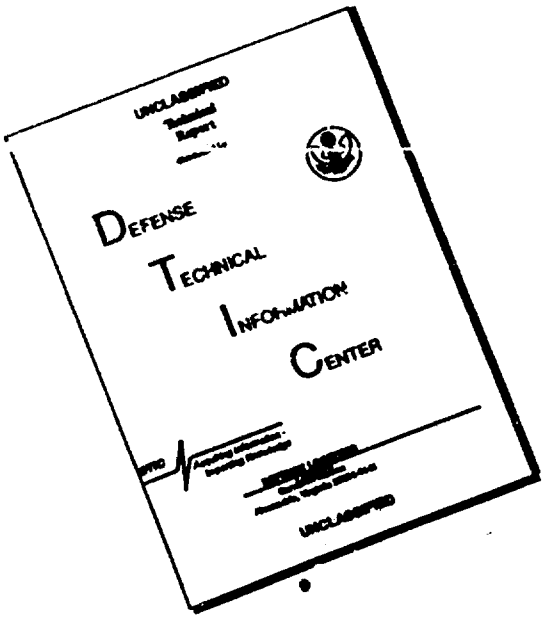

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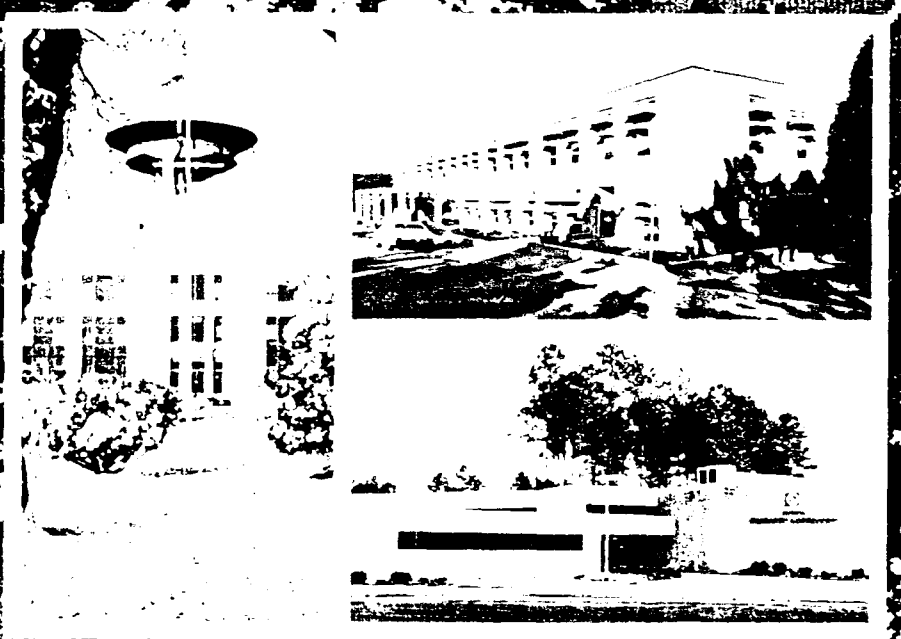

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so well. The data are sufficiently in accord with a lognormal distribution that we can make statistical estimates of upset phenomena in missiles with up to 90% confidence and up to 95% probability. We continue to look for exceptions to our results. As in the case of populations, deliberate human intervention (e.g., hardening of systems to radiation stress) could distort the lognormal distribution. But knowing how missile systems normally behave, such distortions could be characterized and identified as a distinct class.

[Sponsored by SPAWAR and ONT]

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2. S. Kozlowski, private communication. ■

Fig. 8 — Digital moving map display

The U.S. Navy's Compressed Aeronautical Chart Database

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The implementation of digital moving map systems (DMS) aboard tactical naval aircraft has resulted in a dramatic shift from the use of paper charts to digital chart products for naval mission planning and navigation. A DMS computer stores all of the digital maps that are required for a particular mission and displays up-to-date threats, intelligence, or other information as pilot-selected overlays to the base chart. An effective DMS provides pilots with precise, hands-off route selection and navigation information (Fig. 8). The DMS that is currently used on AV-8B Harriers and F/A-18 Hornets was originally designed for night-attack air missions, since the system provides valuable positional information when visual flight navigation is limited. In direct support of these navigation and mission planning systems, the Naval Research Laboratory-Stennis Space Center (NRL-SSC) is developing the Compressed Aeronautical Chart (CAC) database [1].

CAC Overview: CAC is a global, seamless database of scanned aeronautical charts at six different scales (ranging from 1:50,000 to 1:2,000,000). CAC data are derived from the Defense Mapping Agency (DMA) ARC (equal Arc-second Raster Chart) Digitized Raster Graphics (ADRG) database, which is a collection of charts that have been scanned into red, green, and blue pixel components. NRL-SSC digitally compresses ADRG by 48:1 to generate CAC, which is mastered onto Compact Disk-Read Only Memory (CD-ROM). NRL-SSC has been processing CAC since April 1990, and DMA distributes CAC to the navigation community as a standard product. The following sections briefly describe the steps that are involved in processing ADRG into CAC, including a map projection transformation and two compression phases, and relevant research efforts.

Projection Transformation: CAC is stored as a seamless, global database such that the transition from one source chart to another is transparent to the pilot. The data are stored in discrete 50.8-mm (2 in.) square segments of source chart that cover the entire globe (Fig. 9). The model is known as the Tessellated Spheroid (TS) and was originally developed by Honeywell, Inc. In TS, each segment of CAC data is projected onto the DMS display in an equirectangular projection. Transformation from the DMA ARC system to TS is accomplished with a neighborhood averaging function that effectively reduces the image resolution from 10 pixels per mm (the resolution at which ADRG data has been scanned) to approximately 5 pixels per mm and results in a 4:1 data compression. This reduction in resolution is required for compatibility with aircraft displays.

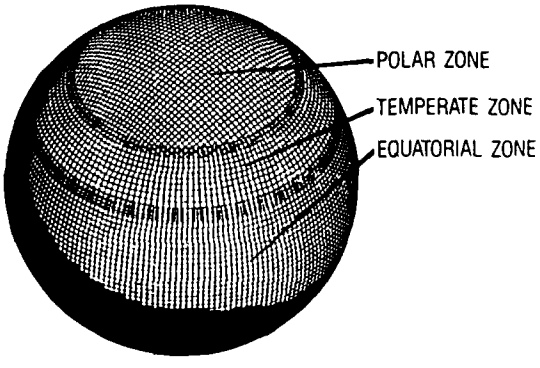

Fig. 9 — Tessellated spheroid model

Color Compression: Each ADRG pixel is 24 bits long: 8 bits each of red, green, and blue (RGB) intensities. Thus, more than 16 million (2^{24}) possible colors may exist in the ADRG database. The Navy DMS system can display only 256 (2^8) colors: 16 colors are reserved for graphic overlays, and 240 are used to display the chart images. Consequently, data storage requirements are reduced from 24 bits per pixel (bpp) to 8 bpp. Following the transformation from ARC to TS, ADRG data undergo a 3:1 color compression in which each 24-bit pixel is replaced by a similar 8-bit color. Color compression is achieved by subjecting the image data to a color vector quantization process that selects the closest match from 240 8-bit colors in a predefined palette to represent each input pixel [3]. A decompression color table is also generated to convert each 8-bit code back to its original (or close to original) RGB value for DMS display. Because the number of possible colors that can be used to represent each pixel has been reduced from 16 million to 240, this compression is not lossless. However, any observable loss of information is usually perceived as a normalization of the map colors and does not sacrifice image integrity.

Spatial Compression: A second compression is performed to further reduce data storage requirements. This is referred to as "spatial" compression, during which each nonoverlapping set of 2 × 2 pixels in the color-compressed image is replaced by a 1-byte codeword. Because each color-compressed pixel is 1 byte (8 bits) long, this represents a 4:1 compression. The method by which a fixed set of best-fitting codewords is chosen to represent all of the image's 4-pixel patterns is based on color vector quantization [3]. Spatial compression is not lossless but, as in color compression, the loss of information is not significant for DMS applications.

Research Efforts: The original ADRG ⇒ CAC compression algorithms were developed by Honeywell, Inc., and Honeywell maintains proprietary rights for that software. Consequently, the source code for those algorithms is not available to the Navy, and the software can never be ported to any computer other than that for which it was developed (a VAX/VMS system). Over the past two years, NRL-SSC has developed a comparable compression method that would be distributable and installable on any government computer system. This year, NRL-SSC mastered a prototype CD-ROM, which contains CAC data that were compressed with this new software, and distributed it to more than 20 government agencies for evaluation. Although the evaluation is not complete, preliminary results indicate that the NRL-SSC compression method is comparable or superior to the original in producing quality chart images. NRL-SSC introduced a "clean-up" stage

to the color compression that reduces the degree of scanner noise and produces a sharper image, particularly in large areas of similar color (such as oceans and desert areas). As a result, text features in those areas are easier to read. Furthermore, NRL-SSC is developing additional color tables that will allow users on limited-color systems (e.g., 16-color PCs) to display CAC data with reasonably good color quality.

Significance to the Navy: The Oceanographer of the Navy recently proclaimed that CAC is the standard aeronautical chart database supporting naval air navigation. F/A-18 and AV-8B aircraft are in the process of replacing all of their paper and filmstrip charts with CAC data. Many of these aircraft relied on CAC for mission planning and navigation during Operation Desert Storm, and the Navy's F/A-18 program office reported that the integration of CAC with their DMS contributed significantly to the success of F/A-18 pilots during that conflict. In addition to the U.S. Navy, several foreign countries, including Kuwait, Finland, Switzerland, and Australia, have recently purchased DMS-equipped F/A-18s and plan to use the NRL-SSC CAC database.

[Sponsored by NASC]

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