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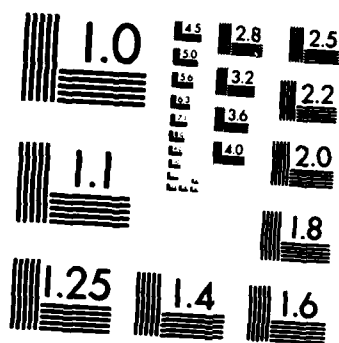
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MAPPING, CHARTING & GEODESY AT THE DEFENSE MAPPING AGENCY

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ABSTRACT

This paper provides an overview of mapping, charting and geodesy (MC&G) programs at the Defense Mapping Agency (DMA). Conventional maps and charts along with special products are covered. Special emphasis is placed on current and future digital data programs, processes and equipment. Future programs including equipment, techniques and computer assisted cartography are covered.

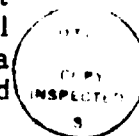
INTRODUCTION

The Defense Mapping Agency was established in 1972 to provide mapping, charting and geodesy (MC&G) support to the Armed Forces and other Department of Defense and government organizations. It was formed by bringing all existing Department of Defense MC&G resources under a single program manager and coordinator. The approximately 9000 people of the Agency are situated in 40 locations around the world. They provide a wide variety of maps and charts and information about the size and shape of the Earth needed for aerospace ground and ocean navigation and for tactical and strategic operations of the Armed Forces. DMA has cooperative mapping agreements with more than 50 nations for the mutual exchange of MC&G information. Over half of DMA's output is in a form other than conventionally printed maps and charts, and includes products on film and magnetic tape for use in specialized machine reading equipment. DMA products are used extensively in aerospace and ocean navigation trainers and for experimental purposes in deriving new items for the nation's MC&G needs. Scientific data and information affecting the safe passage of vessels and aircraft throughout the free world are exchanged with the civil community and countries with navigational interests. All products and services provided by DMA are in response to user stated requirements. These requirements are continually revised to reflect ever changing needs dictated by new and modified weapon systems.

ORGANIZATION

DMA employs approximately 9000 people in 40 locations around the world. The Headquarters is at the U.S. Naval Observatory, Washington D.C., with approximately 180 people. The Aerospace Center (AC), with headquarters in St. Louis, MO, has about 3800 people charged with the responsibility for products and services for aerospace navigation. The Hydrographic/Topographic Center (HTC) with headquarters at Brookmont, MD, has about 3900 people primarily concerned with the topographic mapping of land areas and the hydrographic charting of seas. The Office of Distribution Services (ODS), at Brookmont, MD and 13 other facilities employs about 450 people to provide DMA products in a timely manner to users throughout the world. The Defense Mapping School (DMS) is located at Ft. Belvoir, VA, with approximately 200 personnel. Courses range from basic surveying to management of mapping organizations. DMS also provides tailor-made training for military units in the field. The Inter American Geodetic Survey (IAGS), headquartered at Fort Sam Houston, TX, is responsible for a cooperative mapping and charting program conducted jointly with mapping agencies in Latin America. IAGS has

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about 140 people working in the United States, and throughout Central and South America.

Of the 9000 people employed at DMA, 450 are military. The civilian work force includes approximately 3600 cartographers, 300 physical scientists, 250 geodesists, 100 mathematicians, 400 aeronautical information specialists, 150 negative engravers, 250 photographers, 200 offset pressmen and 300 computer operators. The remaining 3000 people include clerical, administrative, logistics, maintenance, facilities engineering and various other skills.

In addition to the many different skilled people, DMA requires and utilizes many different types of state-of-the-art equipments. Each production center has a Scientific Computer Facility that provides programming and processing service to the entire organization. The principle computers are the Sperry UNIVAC 1100/80 series. Each production center also has a precision photographic laboratory that provides photo services to the entire organization. Capabilities include reproductions, enlargements, rectifications, orthophoto generation and precision reseau printing. Other equipments are used for specific production processes and are discussed later.

CONVENTIONAL MAPS & CHARTS

DMA produces many different standard series of maps and charts plus special maps and charts and related products. Basic photogrammetric and cartographic processes are used to produce most of these products.

In the photo compilation phase, analytical triangulation using aerial photography is performed to generate control over areas void of adequate geodetic or map/chart control. In addition, controlled orthophotos are generated over some areas to provide the required map/chart control base. Personnel involved in the planning function produce a source package that contains control, photography, repromat, maps/charts, intelligence, grids, projections and other source material required for map/chart compilation. From these materials the compiler develops the required manuscripts, i.e., contour, names, vegetation, planimetric, aeronautical, etc. On some charts the planimetric and contour manuscripts are used to develop a shaded relief model. Negative engravers then use the shaded relief model and other manuscripts to accomplish required color separations. After development of the required press plates, either 3 color or 5 color presses are used for printing large quantities of the product. The products are then furnished the Office of Distribution Services for distribution throughout the world. In a typical year over fifty million copies of maps, charts and related products are printed.

Maps and charts are produced in three different modes. New compilation is accomplished over areas where the particular map or chart has never been produced, re-compilation is accomplished when the existing map/chart does not meet accuracy requirements and revision is accomplished within a 5-10 year cycle to update the map/chart detail. For many standard map/chart series, DMA has cooperative agreements with other countries including Canada. These agreements provide for the mutual exchange of repromat materials used in developing the map/chart base. DMA or the other participating country updates and/or adds additional information to the base in accordance with their specific requirements.

Standard Map/Chart Series

Standard series of maps and charts include those produced in standard formats for multi users and purposes. Aeronautical charts are produced on a near world wide basis for use

in mission planning and flying operations at various altitudes. Information is portrayed on the charts to support visual, radar and other aircraft navigation systems. Aeronautical charts produced include 1:5,000,000 scale Global Navigation Charts (GNC), 1:2,000,000 scale Jet Navigation Charts (JNC), 1:1,000,000 scale Operational Navigational Charts (ONC), 1:500,000 scale Tactical Pilotage Charts (TPC), and 1:250,000 scale Joint Operations Graphics (JOG). The JOG is produced in several versions to provide air and ground forces with a common scale graphic. Topographic maps are produced over large areas throughout the world primarily for use by ground forces. Scales of these maps include 1:25,000; 1:50,000; 1:100,000; 1:250,000; 1:1,000,000 and 1:2,000,000 with the 1:50,000 scale map representing the primary series. Hydrographic charts are produced over water and coastal areas throughout the world for ship navigation. Products include large scale Port and Harbor Charts; various scales of Coastal Nautical Charts; small scale General Nautical Charts; Bottom Contour Charts; and various types of planning charts.

Special Maps and Charts

These maps and charts include those produced for a single user or purpose and in many instances on a one time basis. DMA produces over 100 different products of this nature each year. Included are charts or mosaics over weapon test ranges; training charts; weather charts; orthophoto maps, city plans; and thematic maps/charts to show vegetation, population, cloud coverage, etc. Other specials involve the placement of special overprints on the standard series maps/charts.

SPECIAL PRODUCTS

DMA produces many products other than conventional maps and charts. These products have more specific applications and in some cases are produced for single users. An example of such a product is the navigational filmstrip. These filmstrips contain from 50-185 frames of selected Aeronautical Charts. Some have a 35mm format while others are six inches wide and 18 feet long. These products are used in aircraft that are equipped with moving map displays. The filmstrip is projected on a cathode ray tube with the position of the aircraft represented by a fixed symbol in the center of the screen. The map display moves under the symbol at a speed and direction proportionate to that actually being flown.

Flight Information Publications (FLIPs)

FLIPs consist of textural and graphic information required to plan and conduct a flight and accomplish a landing under varying weather conditions. Emphasis is on information required for navigation under instrument flight conditions. These products are produced on a near worldwide basis to provide required flight information in the same format for all free world flying operations. Publications are tailored to the planning, enroute and terminal phases of flight and are updated and distributed every 56 days in most areas of the world. As an example of the magnitude of the program, over 25,000 copies of the publications are produced and distributed every 56 days for just the Continental United States. DMA has agreements with several other countries including Canada that involves both the exchange and sale of FLIPs over common areas of interest.

Support of Space Program

DMA provides unique products to the National Aeronautics and Space Administration (NASA) in support of the space program. For each manned space flight various types of air/sea search, rescue, tracking network and landing site graphics are provided. In addition lunar surface charts were provided for all Apollo moon landings. Current efforts

involve providing a variety of operational, navigational and special graphics used by flight crews, mission control and recovery forces for the space shuttle missions.

Geodetic and Geophysical Data (G&G)

G&G data consists of gravity data and launch site and target positions required for long range missile navigation. DMA maintains and operates a gravity library that contains several million gravity readings throughout the world. This data is used to develop detailed variations in the earth's gravitational field around missile launch regions and more generalized variations throughout the remainder of the missile trajectory. Gravity data is also utilized in the development and refinement of the World Geodetic System (WGS). The WGS provides a worldwide frame of reference with datum origin at the earth's center of gravity. Many of DMA's products are produced on WGS. Transformation programs are continually refined to allow conversion between WGS and local datums, i.e., North America, European, etc.

Precise Positioning

Existing aircraft and missile navigation systems require accurate target, launch and associated navigation point positions in a specific frame of reference. Studies have shown that existing maps over many areas cannot provide positional data within required accuracies. The cartographic errors within each map sheet plus the nonpredictability of errors when measurements are made across two or more map sheets cause unacceptable results. In addition, the inability to make positive identification of some points of interest on maps causes additional errors.

The problems associated with using maps for point positioning have been eliminated through the use of geodetically controlled aerial photographs. Several techniques are used to control the photographs. Once controlled, positions can be accurately derived for any point identifiable on the photograph. One of the techniques used to meet current positioning requirements involves identifying and measuring available geodetic control and common photo points on selected stereo photography covering the area of interest. An adjustment program on a large computer is used to assemble all photographs into a single homogeneous solution. This final solution comprises an assembly of geodetically controlled photographs, which is a composition of the best geodetic and photographic data in that area. Once these controlled photographs are available, required targets, navigation points or any point of interest can be identified on the photographs and positional data derived within required accuracies. This process also provides required control used in the production of other DMA products including maps, charts and digital data.

In the triangulation process described above, stereo comparators are used to make required measurements of control and common photo points on the photography. DMA uses TA3 computer assisted instruments with a measuring capability of ± 3 micrometers precision. The TA3 consists of a three stage comparator and an on-line mini computer to perform pre and post processing as well as real time instrument control.

Once the positioning data base comprised of geodetically controlled photographs is completed, users submit requests for positions of targets and navigation points. Accurate coordinates are derived from the data base and provided the user in the desired format. An example of the type of positioning data derived is accurate relationships between radar significant navigation points and targets used for navigation of advanced aircraft. The data base is also used to provide control points for map, chart and digital data production in areas void of adequate map or geodetic control.

Deployable Point Positioning Data Bases (PPDB)

Increased emphasis is being placed on acquisition of deployable positioning systems by military services to provide an in-theater positioning capability over key contingency and training areas. The objective is to use DMA produced point positioning data bases (PPDB) with highly mobile and non-complex equipment to rapidly derive positional data within required accuracies and eliminate the previously mentioned problems when using maps for point positioning. The concept of field positioning involves development of geodetically controlled photographs and associated computer data to constitute a deployable point positioning data base (PPDB). These data bases can be used with portable equipment in the operational area by military commands to derive precise coordinates of any feature that can be identified on the data base photography. DMA is currently producing deployable PPDB over large areas. The process of producing these PPDB uses the same concepts as the analytical triangulation process previously described. Aerial photography is collected in sufficient quantity to give stereo coverage over the entire area of interest. Control points along with points common to two or more photographs are identified and measured with the TA3 stereo comparators on each photograph. A large computer program is used to mathematically tie all the photographs into a single homogeneous solution. This resulting data along with the hardcopy photographs constitute the PPDB. With appropriate hardware and software this PPDB can be used to derive precise coordinates of any identifiable feature. After this process is completed, the controlled photographs and numerical data is formatted for use on whatever equipment the user has in the field.

Currently all deployable PPDB are being developed for use on the Analytical Photogrammetric Positioning System (APPS). It is specifically designed to exploit deployable PPDB. The system is comprised of a measuring instrument and a desk top calculator. It is a highly mobile desk top system weighing approximately 400 pounds. All military services have accepted the APPS as the standard system for field exploitations of PPDB. The process of using the APPS and PPDB for deriving precise positions follows. A PPDB package containing controlled photo chips, numerical data on cassette tapes and area indexes is provided by DMA to users having APPS. Any point for which precise coordinates are required is identified to the APPS operator normally by a rectified photograph. The correct stereo pair of photo chips covering the desired point is identified from the index, retrieved and set up on the measuring device. The appropriate cassette tape containing numerical data for the photo chips is retrieved and placed in the cassette memory device on the calculator. Reference points on the photo chips along with the point of interest are measured and processed to provide required coordinates. This process can be accomplished in 15-30 minutes. This relatively simple system in addition to providing a rapid response capability, can provide positional data that meets current accuracy requirements. All services have obtained this field positioning capability. There are over fifty of these systems being used by Army, Air Force, Marine and Navy organizations throughout the world.

DIGITAL DATA

Increased emphasis is being placed by DMA on developing digital data bases. This process involves extracting significant terrain and cultural data from cartographic and photogrammetric source materials and storing the data in an ADP file. With appropriate hardware and software these files of digital data can be rapidly converted to a variety of MC&G products required by current and future weapon and advanced training systems. As a result of the development of missile, aircraft navigation and training systems requiring digital data, DMA has implemented a program to generate digital data over a large portion of the world. The process of developing a digital data base of the earth involves

using an appropriate combination and quantity of numbers to represent characteristics of the earth's surface. This information must be of sufficient detail to generate through appropriate hardware and software products required for use by advanced weapon systems to navigate from one point to another on the earth's surface. Three types of data are collected and placed in the ADP file. First, terrain elevations at an approximate 100 meter interval are collected over large areas. Second, information is collected to represent cultural or man-made features. Included is information to represent location, shape, size and surface composition of features such as buildings, bridges, storage tanks, powerlines, etc. Third, information is collected to represent landscape characteristics of the earth's surface. For example, some combination of numbers is used to represent whether an area is water, trees, sand, rock, normal soil, etc. One of the major applications of digital data is digital aircraft simulators that have recently been developed. The digital data is used to simulate radar return over military training and operational areas. Therefore, the digital data collection processes must be adequate to capture the required radar significant information.

Digital Terrain Elevation Data (DTED) Collection

DTED is collected from both maps/charts and aerial photography. Medium scale maps and charts are used as the basic source in areas where they meet accuracy and currency requirements. The process involves digitizing contours and geomorphic information such as ridgelines, drainage, coast lines and lakes from an existing map or chart. The Automated Graphic Digitizing System (AGDS) is used for this process. The required vertical data on the map/chart is raster scanned using a ruby laser beam. The AGDS computer converts raster data into vector data so it can be displayed on AGDS edit stations. The cartographer displays the digitized data on a CRT, enters elevation values and performs edits for completeness and correctness.

AS-11 analytical stereoplotters are used to compile DTED from photography. The AS-11 is a computer assisted two stage instrument with a precision of ± 4 micrometers. The on-line computer performs pre-processing and assists in model set-up using control generated from the analytical triangulation procedure previously described under precise positioning. The computer assisted compilation consists of profiling across the stereo model, with the cartographer's function that of maintaining a floating dot on the earth's surface. The on-line computer controls profiling and captures heights at approximate 100 meter intervals and stores them. In addition to this manual method, DMA has instrumentation to automatically collect DTED. The Automated Compilation Equipment (ACE) is a modified AS-11 system that employs laser scanning techniques to derive heights. DMA also has AS-11-B1 instruments that utilize shades of gray electronic correlations and UNAMACE instruments that employ electronic correlation techniques.

After DTED is collected using either the AGDS or analytical stereoplotters it is processed on the UNIVAC 1100 computer system where editing and placement into a standard DMA format is accomplished. The final output consists of one degree cells of elevation data and appropriate header information.

Digital Feature Analysis Data (DFAD) Collection

The other half of DMA's digital data production involves the man-made and landscape features on the earth's surface. Primary source materials include aerial photography and controlled orthophotos. The orthophotos are produced from existing DTED and aerial photography using the Off-Line Ortho Printer System (OLOPS) or the Replacement Photographic Imagery Equipment (RPIE). The DFAD compilation involves reviewing the source imagery in stereo utilizing B&L Zoom 240 stereomicroscopes. The functions here

involve photo interpretation and measurements to determine heights. First those features to be included in the data base are identified. Surface material composition for each selected feature is determined along with height information. Landscape characteristics are determined according to approximately 12 different categories. All of this descriptive data is appropriately coded and entered into a central processor via an analyst's work station. The analyst also prepares a manuscript where all selected features are delineated and assigned a unique identifier corresponding to the descriptive data identifier. The manuscript is keyed to the controlled orthophoto to accomplish required positioning and insure that the DFAD fits the DTED. The AGDS previously described is used to digitize the manuscript. The data is then processed on the UNIVAC 1100 system that includes editing and bringing the descriptive data and manuscript files together into a single file. The final output consists of one degree cells of DFAD data and appropriate header information in a standard format.

Data Base Management

After DTED and DFAD collection, editing and processing is completed, the data is placed into a data base. This represents the final product and the data is then available for distribution to users. The data base consists of the actual digital data stored in sets of 1 degree x 1 degree cells, an automated directory defining data availability and data base management software. Prior to final placement into the data base, additional edits and verifications are performed to assure compatibility with adjacent cells. When a request for data is received, a query is ran against the directory and a copy of the data is generated. The data is verified to ensure that it covers the area requested and has been extracted from the the data base correctly. The data is then sent on magnetic tape to the requester and a distribution audit trail posted.

Digital Data Processing

After the master digital files are developed, it is normally up to the user to develop or obtain the necessary equipment and programs to convert the digital data into required products. The development of digital data over large areas is an extremely costly and time consuming process. However, once available the digital data can be processed through appropriate hardware and software to generate a variety of products on a rapid response basis. For example, with a computer and plotter the terrain elevation data can be used to generate profiles representing how the terrain would appear for a particular flying altitude and heading or for someone standing on the ground looking in a certain direction. The combined digital files can be processed through a computer and printer to generate simulated radarscope scenes for a particular altitude and heading. Transformation programs can be used to extract required information from the master DTED and DFAD files, assign radar reflectivities based on the stored data and generate an on-line file that allows training to be accomplished on digital radar simulators. The digital files can also be transformed to other digital formats for storage in on-board aircraft and missile computers for utilization by navigation systems requiring digital data.

Digital Data Quality Control

Since DMA produced digital data is being used in many weapon and training systems, effective quality control procedures must be used to insure the integrity of the data. As mentioned previously, edits and verifications are performed during the production processes, prior to placement into the data base and after retrieving data from the data base. Some potential problems that are addressed in digital data quality control procedures include missing data, wrong area coverage, adjacent areas or cells do not match, data does not meet specifications with respect to accuracy or resolution and other

problems that cause simulations or other products generated from the data to look questionable.

Various computer programs and plots are used to check data compatibility, data completeness, area coverage, etc. However, some of the principle quality reviews involve pictorial representations of the data. One of the systems used is the Image Manipulation Station (IMS). This is a low cost system containing a minicomputer and raster display color graphic CRTs. It is used for reviewing DTED in various modes--color coded by elevation, shades of gray, pseudo-stereo, selectable magnification, shaded relief, convolutions and actual elevation data values. The cartographer reviews the CRT displays for data completeness and general terrain correctness. An additional check is made to ensure that elevation values for common points on adjoining cells have the same value. If discrepancies are found, the data is returned to the producing organization. When the data is received back from the producer, the data is viewed again to verify that necessary corrections were made. The IMS is also used to review data prior to distribution to users. Another system used is the Digital Data Base Analysis System (DBAS). It is similar to the IMS except it has more advanced color graphic CRTs that provide better resolution and allows several cells of data to be viewed simultaneously.

A more advanced system used for quality control and studies of digital data application is the Sensor Image Simulator (SIS). It contains an advanced minicomputer, an array processor and color graphic CRTs. This high speed system in addition to displaying pictorial representations of DTED similar to the IMS and DBAS can use combined DTED and DFAD data to generate radar and other sensor simulations. It allows for interactive query of individual features in the simulated sensor scene to determine the corresponding data base elements responsible for the simulated features. This system in addition to providing an additional quality control capability is used to better understand what features are significant to various sensors for subsequent product and production specifications. The system also allows several adjacent DFAD cells to be displayed simultaneously in terms of colors or radar reflectivities to verify compatibility of cells.

FUTURE PROGRAMS

New Equipment and Methods

DMA is scheduled to implement into production new and more sophisticated equipments and processes in the near future that will significantly improve production programs. A system undergoing test and acceptance at the present time is the Computer Assisted Photo Interpretation (CAPI) System. Its intended use is for DFAD production. CAPI is a stereo two-stage system that will operate in a similar computer assisted mode as an analytical stereoplotter. Inputs will be control generated by analytical triangulation methods and stereo imagery. The system will allow a cartographer at an analyst work station to view imagery in stereo, select features of interest, enter descriptive data into a central processor and digitize selected features. This eliminates the current requirement to produce a manuscript to be digitized and processed on the AGDS. CAPI output will be a completed DFAD cell ready for final quality review and processing. Approximately 30 analyst work stations can be tied to one central processor.

Another system currently undergoing test and acceptance is the Clustered Processing System (CPS). This is a "mini-computer" center comprised of three advanced mini-computers, plotters, disc and tape drives and interactive edit stations that contain advanced high resolution color graphic CRTs. This system will allow all processing of digital data to be accomplished in the producing organization without going to the UNIVAC 1100 system. The advanced plotters and edit stations will provide enhanced

quality control and allow corrections, additions or deletions of data to be accomplished at the interactive edit stations.

A system that has been available but not fully implemented into production is the Digital Interactive Multi-Image Analysis System (DIMIAS). This system is comprised of a mini-computer, array processor and color graphic CRTs. It will be used primarily for computer assisted automated classification of landscape features in developing the digital feature analysis data base. DIMIAS is currently used to automatically classify features from digital LANDSAT multi-spectral data. The system software is being upgraded to enhance capabilities and efforts are underway to incorporate it into the production pipeline.

Automated Map/Chart Production

Efforts are currently being directed toward using digital data with existing equipments to automate portions of the map/chart production process. It is important to recognize that digital data developed by DMA has been in response to specific user weapon system requirements. Although much of the information in the digital data base is applicable to map/chart production, the existing data base is not tailored to such applications. Thus, it is necessary to develop software for effective utilization of the digital data in map/chart production.

Computer programs have been developed to generate contour plots from digital terrain elevation data. These plots are then used for portraying required contours on maps and charts. Some manual efforts are still required for smoothing and adjusting the contours to fit the map/chart base. Software refinements are continuing to minimize these efforts. On some DMA produced charts, different shades of purple are used to portray expected radar return around cities and other radar significant features. A radar analysis using photography and other source materials is required to compile the necessary information for portrayal on the chart. Computer programs have been developed to generate the required radar information overlays from the digital feature analysis data base. This saves time in addition to providing more detailed information than the manual method.

Existing systems such as the Automated Graphic Digitizing System (AGDS) previously described are being used to develop a capability for automated color separation.

Compilation manuscripts are still manually prepared from source material. The manuscripts are raster scanned on the AGDS, the raster data converted to vector data and placed on a magnetic tape. The interactive edit station is used to verify the data and make necessary corrections. The line segments are also "tagged" at the edit station with an appropriate code that represents what each chart feature is, i.e., road, railroad, contour, etc. This final AGDS digitized and tagged data is archived for later chart revisions. The data is then processed through Graphic Line Symbolization System (GLSS) software on the UNIVAC 1100 system. GLSS contains all the codes used in the "tagging" process that represent chart symbols for that particular type chart. The GLSS program builds a tape containing plotting instructions for use on a Gerber plotter. The Gerber has a film (photo) plotting capability and is used with the GLSS tape to produce the required film positives (color separations).

The existing automated color separation will be enhanced in the future with other equipments and a digital data base containing more chart feature data.

Both raster and vector systems will be used to digitize, edit and process data from both manuscripts and printed maps/charts. Equipments such as CAPI will collect feature data from photography that is applicable to map/chart production. Advanced edit stations and

plotters will be used for automated color separations. As more and more map/chart feature data becomes available in the digital data base, it will become the primary source in lieu of hardcopy source materials.

Future Digital Data Requirements

Future digital data requirements will include new applications, better resolution, auto carto utilization, improved production methods, new formats, improved storage and handling and more sophisticated data base systems. Due to the large cost and time involved in producing the current data base, the development of a separate data base to meet each need is near impossible. Therefore, DMA will continue to participate with military services and contractors to develop one master data base that best meets the total need. Where certain requirements cannot be met, the existing data base will be enhanced in some cases to meet those requirements.

The current data base is being developed primarily for radar simulation. Efforts are under way to build digital simulators for other sensors. For example, the development of a visual simulation system that would operate with digital data is under way. Prototype digital data bases are being developed by DMA to support these efforts. Maximum use will be made of the existing data base in providing data required for visual and other sensor simulation.

Several advanced guidance systems using correlation techniques are currently undergoing test and evaluation. In each system some type of sensor in the vehicle takes measured scenes over pre-selected areas. On some systems these scenes are then converted to digital format by the on-board computer. It is necessary to develop from digital data simulated digital or hardcopy representations for the same sensors at the same altitudes. The on-board computer then correlates the measured and stored scenes in order to make position updates. The types of systems being considered include optical, radiometric and pulse Doppler sensors. DMA is providing test data for all of these systems to support the development and test and evaluation. Should these types of systems become operational, digital data may be required over and above that previously described in order to meet more rigorous specifications.

Other Future Programs

DMA will continually acquire state-of-the-art equipments for digital collection and processing and computed assisted cartography. This will include photo digitizers and other equipments necessary to automate the feature extraction process. Improved map/chart digitizers and interactive editing systems will also be acquired. The development of a digital multi-use feature file is also planned. Past and current efforts have been directed toward developing digital data bases that meet specific needs. Such data bases have to be adapted or enhanced for other applications such as automated cartography. Plans are to develop a master data base containing all the necessary information to generate both digital and hardcopy products. From this multi-use data base information needed for automated cartography, radar and other sensor simulation, correlation systems, planning, etc. can be extracted. Improved capabilities are also being developed to store and manage massive columns of digital data in centralized data bases. The ultimate goal is to have an all digital capability sometime in the 1990s.

SUMMARY

DMA produces a wide variety of conventional maps and charts and special products including precise positioning and digital data over large areas. More and more resources

are being directed toward providing information in digital form, yet the production of traditional paper maps and charts will continue to be required. Only by utilizing the newest and most sophisticated of the new technology has DMA been able to keep up with requirements dictated by advanced weapon and training systems. Even with the availability of the latest technology, much of the effort remains manpower intensive. It takes highly skilled professionals to effectively utilize the multi-faceted equipment and emerging techniques now available. Today's cartographer must acquire a broader base of special skills and a wider range of technical expertise than ever before. They must be more adaptable and able to assimilate this extensive and continually changing array of information and new tools. When DMA reaches an all digital posture, highly skilled cartographers will still be required to effectively utilize the most advanced technology for producing in a rapid response mode a wide variety of quality MC&G products tailored to meet ever changing requirements.

END

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