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Outlook on Future Mapping, Charting, and Geodesy Systems*

The Defense Mapping Agency of the 1990's will be a data-base-centered production system providing information to a wide range of users in flexible application-oriented forms.

Abstract: *Changes are taking place throughout the Mapping, Charting, and Geodesy (MC&G) community—changes in the way that source data are collected, products are developed, and information is presented to the user. These changes will have a profound effect on the community over the long range, and the trends are observable now. This paper addresses the changes that are taking place within the Defense Mapping Agency (DMA), together with the forces behind them. The main thrust of DMA's R&D program is described, and is linked to major advances in key digital technologies. A view of DMA in the 1990's is presented, portraying a data-base-centered production system providing information to a wide range of users in flexible, application-oriented forms.*

Introduction

The techniques of map and chart production in the Defense Mapping Agency (DMA) have been evolving for many years, and have now reached an advanced state of development. Processes and equipment have become available which greatly reduce our costs and improve our performance in high-volume production operations. And yet we are nowhere close to a development plateau. Continued introduction of advanced technologies into operations, together with a broadly-based program of sophisticated needs, are leading to demands for a rapidly expanding range of mapping, charting, and geodesy (MC&G) products and services. At the same time, new and improved methods of collecting source data, typified perhaps by the GEOS-3 and Landsat satellite programs, are imposing increased expectations upon us by our associates and counterparts. The forces of change are evident all around us, and we have to continue to change too, in order to remain responsive to the organizations that we serve.

Consider for a moment the situation we are likely to be facing by 1990. We will still be producing conventional paper maps in large quantities. But other demands will have created a need for a wide range of limited-volume, special-purpose, map-like, digital products in computer-compatible form. In addition, rapid increases in sophisticated communications and computer-assisted data handling and display systems, and the general shortening of allowable reaction times through all elements of the community, will have led to a strong need for information products, as opposed to only map products.

The "bottom line" is an emerging need for improved flexibility in our product types,

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formats, and media, and an improved responsiveness both in generating and updating special-purpose products and in handling queries from key elements under rapid-response conditions.

Elements of Change

The signs of change within DMA can be observed today across a broad front. Consider what is happening in our gravity field mapping activities, for example. Land and ocean surveys are conducted to measure the gravity anomalies at many sample points over very large regions, and several types of map-like gravity-based products are then formulated to support various needs and operations. Traditionally, the surveys have been carried out using transportable gravimeters on land, and ship-mounted gravimeters at sea. The process is reasonably accurate, but slow and expensive, and the cost of the surveys is a function of the required sampling density and coverage area.

The emergence of moving-base survey systems offers the potential for major reductions in survey costs without sacrificing measurement accuracy, and the more technologically advanced of these systems offer accuracy benefits as well. The NASA-sponsored GEOS-3 satellite, for example, and its SEASAT successor both carried extremely accurate radar altimeters that allowed nearly-continuous sampling of the undulation of the geoid over the world's oceans. It is extremely important to note that GEOS-3, a single satellite mission, provided the most revolutionary geodetic and geophysical data coverage over the oceans of the Earth's surface.

In another vein, the growing synergism between the geodetic community and the inertial navigation community over the past ten to fifteen years has been widely noted. While this has been happening, the experimental utilization of high-precision inertial navigation systems as survey vehicle positioning devices in various types of survey applications has been growing.

The advent of the Global Positioning System (GPS), a high-precision satellite-based radio navigation network, promises to extend the use of inertial navigation equipment for moving-base gravity survey applications in a different and much more powerful way. Very-high-accuracy inertial navigation systems flying through a poorly-modeled gravity field will experience a rapid growth in position and velocity errors, which can be sensed directly by an on-board GPS receiver. The measured navigation errors in the inertial system outputs contain information on the magnitude of the gravitational disturbances. Optimally-designed data processing algorithms can be formulated which will permit efficient estimation of the disturbance components. This "direct recovery" method is a very powerful technique, and impressive accuracies appear obtainable. Another variation of this thrust could be found in a GPS aided ground mobile inertial positioning system similar to the Inertial Positioning System (IPS) in use today.

Moving now to the cartographic side of our operations, we find a similar situation developing. New types of source data are becoming available. The large Format Camera, being considered by NASA for deployment in space in the early 1980's, offers the community a source of worldwide photographic coverage at improved resolutions and at comparatively low cost to the user. An alternative program under consideration by NASA, STEREOSAT, could provide full stereo photography over correspondingly large regions, with the data being collected in digital form.

Our product line is expanding to keep pace with the needs of our customers, and we find that digital products, such as terrain elevation matrices and radar correlation data sets, constitute an increasing fraction of our total production volume.

Trends Toward Digital Data Bases

Three fundamental driving forces underlie a shift at DMA towards a reliance on digital data bases for mapping, charting, and geodesy operations. These are the need for product flexibility, the need for responsiveness, and the need to reduce production costs. Flexibility represents a shift away from the encyclopedic format of the standard map and chart product toward the presentation of information tailored to user needs. Our requirement to be responsive to a wide variety of user requests, and to respond to these requests in increasingly short time frames, forces consideration of the generation of special purpose MC&G products produced in a wide range of quantities, from single copies to multiple printed editions. The cost reduction pressures which DMA constantly shares with other government agencies include the needs for optimizing the utilization of available manpower to improve, shorten, and speed up the production flow for MC &G products, and to provide commonality among many largely-digital extraction processes utilizing modern MC&G production systems. Processing cost considerations also dictate a need to share data bases both

within our organization and among DMA and other agencies in the MC&G community. The flexibility and convenience of machinery to build the digital data bases promise to enhance greatly our capability to share our information.

The technology of data base management, which has been a field of both academic and commercial research and development, provides a major technological base in support of the concept of centralized, nonredundant, and complementary digital data bases for MC&G applications. In this context, new ideas about the fundamental operations of MC&G product development have been forthcoming, which tend to revolutionize the way in which the process of developing MC&G products from the wide variety of available sources is conceived. Under this technology, it is possible to regard raw data in digital form as fundamental "truth" data which is both archivable and transformable by using the technology of digital data base design and updating. The processes of compilation and MC&G data selection for inclusion in the product can be accomplished in the framework of modern data base query/response processing, including interactive processing with heavy man/machine interaction. The digital products can be regarded in this context quite simply as reports tailored for a particular user, generated in response to that user's specification, and derived by relatively straightforward data base selection and formatting techniques from a collection of digital data bases. Other attributes of modern digital technology also support the capability to convert MC&G labor-intensive processes to digital-data-base-centered processes. The key point here is that a very complex, complete, and readily-tapped data processing technology base exists which can serve to help us respond to the economic and time pressure imposed by the modern MC&G environment.

The advantages of the application of data base management technology for DMA will be realized by a concerted effort on the part of our technical and managerial organizations along the following lines:

- Data collection and processing requirements will be consolidated, emphasizing the commonality of feature classes and fundamental geo-based data types and deemphasizing the importance of mapping scale, source product formats, and source data differences.
- There will be a concerted effort to develop a range of standards for digital data storage, communication, and processing interfaces across the agency. This will also include consideration of data storage and data exchange standards for interaction with other members of the MC&G user community.
- A concurrent development of efficient multipurpose data processing techniques will be accomplished. Feature class selection, user output format, mapping conventions, and the like will be largely controlled by processing input parameters as opposed to specific product line consideration.

All-Digital Production

The gradual introduction of digital processing capability into the MC&G production mainstream, and the parallel move toward digital data bases as the outputs of the data processing operations, are elements of a much broader trend within our mapping community. The trend is a result of observed rapid increases in capability and decreasing cost in such key digital technology areas as mass storage, communications, processing, and displays. These technologies offer the potential for greatly improved performance (throughput, response time) and reduced operating costs in MC&G production operations, by making possible the conversion of our current film-based production plant to an all-digital system within something like ten years. In this new system, the source data will be converted to digital form when it enters the production flow. It will then be stored, managed, processed, and manipulated by digital techniques.

A major stumbling block to date in the conversion of MC&G processing to the digital domain has been the tremendous data volumes created by digitizing the source data. However, as a result of continuing commercial pressure and government-sponsored research and development activities, drastic improvements in the area of very large mass storage systems have been forthcoming. New concepts, new devices, and new data manipulations techniques have been postulated in this area in the last few years, and convincing laboratory demonstrations have been provided for such approaches as optical video disk storage of tremendous volumes of digital data. Simultaneously, the older technology of magnetic digital data recording has exhibited continued improvement at a very rapid rate, forcing the new technologies to aim at a rapidly moving target. The MC&G community, therefore, has the option of utilizing a mature and highly capable technology in the near- and mid-term, with the potential for orders-of-magnitude improvement in data base volume

capabilities and data base utilization rates in the mid- to long-term. Concurrent with the fundamental storage technology developments have been developments in collateral systems for managing, manipulating, and processing the digital data on the mass storage devices.

Our consideration of the requirements for digital data communication within a postulated largely-digital production process rapidly leads to a requirement for new communications paths. As with the mass storage technology, however, the digital communications technology has exhibited very strong growth in capability and in range of approaches which will support our effort to realize this kind of communication capability. Our problem is to develop an overall operations concept for MC&G processing, and apply the digital data communications technology in an optimal way.

In the area of digital processing as it relates to MC&G applications, extremely strong improvements in processing power and processing costs have been characteristic of the industry for the past ten to twelve years. A tremendous range of digital processor architectures and options is available to us, with low-cost special-purpose processing well within reach for many of the critical MC&G applications. Our challenge is to find an optimal mix of special-purpose and general-purpose processing, and to utilize the results of industry-wide research and development into distributed processing concepts and techniques.

Concluding Comments

Our futuristic all-digital production system will offer major opportunities for improvement with respect to the current baseline—improvement in the areas of throughput, response time, operating costs, and flexibility to respond to changing scenarios. It is not without risk, however, and many major problems remain to be resolved. The initial investment is high. We have initiated a broadly based program of development, combining digital hardware technology applications and the generation and testing of digital image processing algorithms and techniques, for the purpose of reducing the risk and quantifying the benefits before proceeding with acquisition of the system. After the initial concept is developed, the system will be bread-boarded in stages, and hands-on testing by our knowledgeable production personnel will be carried out in order to validate system requirements and resolve human-factors issues before the system specifications are generated.

Today we are an organization producing maps, charts, and geodetic data in a state of transition. We are moving toward the situation depicted in Figure 1 where centralized, unified, and coordinated data bases are the principal repositories of extracted cartographic and photogrammetric information and products are viewed as the specific-purpose assemblage of digitally stored data, generated by numerically controlled devices at the point of use. Physical access and delivery paths will be automatically determined by the system query logic, and ad hoc requests from the field will be routinely handled on a rapid-response-time basis.

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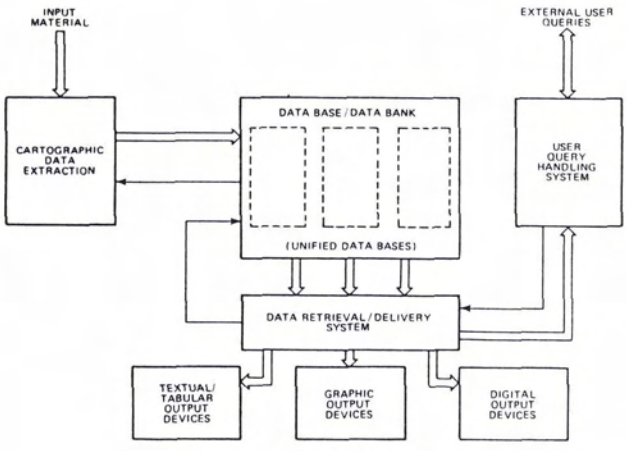

Fig. 1. DMA in the 1990's.