AN APPROACH TO A STANDARDIZED SIMULATOR DATA BASE

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ABSTRACT

The current trend in user requirements for data bases to support visual, sensor, and radar simulation for training is toward real-world data bases that cover large geographic areas. The production of these data bases is an expensive process and typically each new system develops new data base generation software, along with a data base itself, to meet its own specific needs. The result is a large amount of redundant effort, since the same geographic area may be modelled or transformed repeatedly for different applications. This paper will describe an approach to help the Department of Defense (DoD) control the escalating costs of generating and maintaining simulator digital data bases. This approach will be developed through Air Force Project 2851, Common DoD Simulator Digital Data Base/Transformation Program, a tri-service effort which was initiated at the direction of the Joint Logistics Commanders (JLC) DoD Joint Technical Coordinating Group on Simulators and Training Devices (JTCG-STD)

The objective of Project 2851 is to develop a DoD standard simulator data base and common transformation software to support all simulator training devices requiring the use of digital topographic data. The DoD standard simulator data base will provide a common source of digital data that will be specifically compiled to meet training objectives and which will minimize the need to enhance Defense Mapping Agency (DMA) data during the data base generation/transformation process for each individual simulator system. The goal of the common transformation program is to reduce the amount of system unique software for each simulator system. It will promote a greater degree of data base and software compatibility among the many DoD simulator systems. The results of the project should be improved simulator training capability at reduced development, acquisition, and life cycle cost to the Government.

INTRODUCTION

Project 2851 - Common Simulator Digital Data Base/Transformation Program - is a tri-service simulator software applications and data base development program assigned to the Aeronautical Systems Division (ASD) of the Air Force Systems Command (AFSC) by the Department of Defense (DoD) Joint Logistics Commanders. The purpose of the project is to develop a standard simulator topographic data base and to minimize the number of data base transformation programs for various DoD training simulators. The term "simulator data base" in this paper refers to a topographic data base containing a description of terrain relief, and natural and man-made features on the surface described by the terrain. It may contain cartographic, hydrographic and/or topographic features. This paper describes the background and problems associated with the current procedures for generating simulator digital data bases for training simulator applications, the major requirements that will be addressed by Project 2851, the program approach to be taken and related technical support.

BACKGROUND

Topographic data bases are required whenever the simulation involves a visual or sensor capability. Visual systems are required for training tasks such as take-off and landing for aircraft, harbor navigation for ships, and artillery practice for tanks. Sensor simulation systems are required for training tasks involving radar or electro-optical systems such as infrared sensors or low light level television. The data base provides the model from which the simulated image is generated. Data bases used in the past have included model boards built on either a stationary platform or on a moving belt for visual and optical glass plate transparencies for radar. However, the last ten years have seen a shift to computer based simulation systems using a digital topographic data base. Computer image generation (CIG) systems and digital radar landmass simulator (DRLMS) systems now permit realistic visual and radar simulation of real world areas over large geographic expanses.[1]

In an attempt to standardize cartographic and geodetic data base support throughout the DoD, the Defense Mapping Agency (DMA) was formed. The first prototype digital data base was developed by DMA in 1974,[2] primarily in support of radar simulation requirements. However, since that time, DMA data base applications have expanded to include tactical and strategic weapon systems. In 1977, a major revision to the DMA data base was accomplished to improve the detail and descriptive content. The 1977 data base, referred to as First Edition Digital Landmass System (DLMS) data[3], includes two files-terrain elevation and feature analysis. The terrain elevation file consists of a 3 arc-second by 3 arc-second matrix of elevation values which represent the elevation of the earth's surface. The feature analysis file is the more complex of the two and contains a description of all features on the earth's surface, both natural (lakes, rivers, forests, fields) and manmade (buildings, roads, towers, bridges). Descriptions within the feature analysis file include geographic location, feature identification (truss bridge, two lane highway, resi-

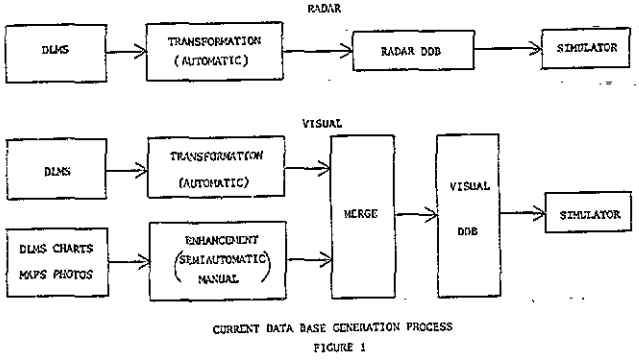
dential building, etc.), surface material category (metal, wood, soil, water, etc.), feature height, percent tree cover, and percent roof cover.

Use of the DMA DLMS is now required as the primary source of information for all DoD simulator data bases. The basic feature content, accuracy, and resolution of the DLMS data have proved adequate for the simulation of low to medium resolution radar systems. The DLMS data has also proved useful for visual and sensor simulation applications provided certain enhancements are added.

DATA BASE PROBLEMS TO BE SOLVED

Data Base Transformation Programs

As described in the previous section, the DLMS data is defined in terms of ground truth physical descriptors and is in a DMA standard format. CIG and DRLMS systems, however, require that the data base be in a format compatible with the particular system architecture. They also require certain descriptors in addition to those included in the DMA data for visual displays (color, texture patterns), and radar displays (feature reflectance codes). In order to convert from the DMA data base to one compatible with the specific simulator system, a conversion program, commonly referred to as a data base transformation program, must be developed. In the case of a visual data base, manual enhancement using additional data sources is usually required to supplement the transformation process. The transformation program development (and enhancement process for visual systems) is performed by the simulator contractor for each new simulator system. Figure 1 illustrates the transformation process for both radar and visual systems.



CURRENT DATA BASE GENERATION PROCESS
FIGURE 1

Unique transformation programs are required for each simulator system for several reasons. Due to the complexity of visual system design, only a limited number of edges or polygons can be used to represent a given scene (typically on the order of 4000 to 8000 edges). Therefore, visual system data base content must be restricted to those features necessary to meet the specific training task. For example, a visual data base used for low level navigation might require emphasis on roads, streams, vegetation patterns, and predominant terrain. On the other hand, a data base used for air-to-ground weapon delivery might require more emphasis on specific cultural objects or surface vehicles. The transformation program must therefore be designed to select those features of importance and use them to produce a visual data base compatible with the visual system architecture. Similarly, the radar data base transformation program must perform the same function to produce a data base compatible with the radar system architecture. Since each system has its own format and content requirements and therefore requires its own transformation capability. a transformed radar data base is not compatible with a visual system, nor can a radar system use a transformed visual data base. In fact, a visual system can seldom use a data base from a different visual system due to differing system capacities or capabilities and unique system or contractor designs. The same problem exists in the radar and sensor areas.

There are several consequences to the current practice of transformation program acquisition. The first is the large recurring cost of software development for every new simulator program involving a visual, radar, or sensor requirement. Visual transformation programs, typically 75,000 to 150,000 lines of code, are a significant part of the software development process. Second, the growth in the number of transformation programs places a burden on simulator computer facilities. Third, maintaining this proliferation of the transformation programs and keeping them current with the DMA data base is and will continue to be a problem. Finally, the effort to create data bases becomes highly redundant. This is especially true for a simulator with visual, radar, and sensor simulation systems, each with data base requirements covering the same geographic area, but in a different format.

As a result of the initial concept development of the data base transformation process and the development of several operational simulators, it has become evident that some additional control of this process is needed. It is highly desireable to reduce the redundant and complex, time consuming transformations and enhancements.

Simulator Data Base Adequacy

As previously explained, DLMS data has been adequate for some recent simulator acquisition programs, while it has required major enhancement for others. However, current DLMS data does not appear suitable for future simulator programs involving high resolution radar and sensors, or visual systems requiring large geographic areas. There are three reasons for this.

First, the resolution and content of the DLMS data base is not adequate for the simulation of new sensor systems such as synthetic aperture radar (SAR), which is capable of ten foot range and azimuth resolution. The current DMA DLMS data is not a one-for-one representation of features on the earth's surface. To be included in the DLMS data base, a feature must meet a set of criteria with regard to type, material, minimum size, and minimum adjacent feature separation, typically on the order of 100 to 500 feet; thus certain features may not be portrayed at all or may be included as part of a homogenous grouping of similar objects. For example, a large feature may represent a combination of individual structures

e.g., residential plat, factory complex, commercial buildings. In some cases, a small town may consist of only one, two or three features. On the other hand typical high resolution sensor systems are capable of displaying a one for one representation of individual buildings and landscape features. Therefore, a significant amount of additional detail would need to be added to the current DLMS data before it would meet the requirements for high resolution simulation applications.

The second data base problem deals with the lack of necessary feature descriptors. The DMA DLMS data was originally defined in support of radar simulation; as such, information unique to visual or sensor simulation applications such as color, surface patterns (runway stripes), and detailed three dimensional information are not contained within the data base. For current applications, the DLMS data requires enhancement which is usually accomplished manually. Although this approach may produce acceptable results over limited geographic areas, a high level enhancement is not practical for extended gaming areas that cover hundreds or thousands of square nautical miles.

The third data base problem is that of availability for specific geographic areas of interest. For any data base product requirement, DMA produces data for a specific area of geographic coverage based upon available allocated resources and assigned project priority. Therefore, a new simulator project or one with a low priority may have a difficult time obtaining the desired area of coverage unless that area coincides with existing data base production efforts. The competitive environment for obtaining DMA support includes not only simulator programs from all three services, but also strategic and tactical weapon system applications such as missile guidance systems, aircraft cockpit map displays, and aircraft navigation aids.

PROJECT 2851 OBJECTIVES AND REQUIREMENTS

Objectives

The problems described in the previous section were recently acknowledged by the Joint Logistics Commander's Joint Technical Coordinating Group on Simulators and Training Devices (JTCG-STD). As a result, in early 1982 the JTCG-STD named AFSC as the lead organization in a tri-service effort to develop a standard DoD simulator data base and common simulator transformation software. The program was designated Project 2851 under Air Force Program Element 64227F. One of the initial steps was to establish a working group consisting of ASD, Naval Training Equipment Center (NTEC) and Army Program Manager for Training Devices (PM-TRADE). The Defense Mapping Agency also serves as a supporting organization. Although funding began in FY84, the initial planning and some detailed in-house efforts started earlier. Project 2851 will address simulator data base requirements in the following three primary areas.

Technical Requirements.

The data base transformation software and standard simulator data base must be compatible with the technical requirements for all types of future training systems. This will include visual, high resolution radar such as SAR, and high resolution electro-optical systems such as infrared and low light level television. In addition, the training systems associated with each of the three services must also be considered i.e., air, ground, and naval simulation systems. The new data base structure and content, and the transformation software must be compatible with the basic architecture and data base processing capability of current state-of-the-art simulation devices, and must also be flexible to permit changes as simulation technology evolves.

Operational Requirements.

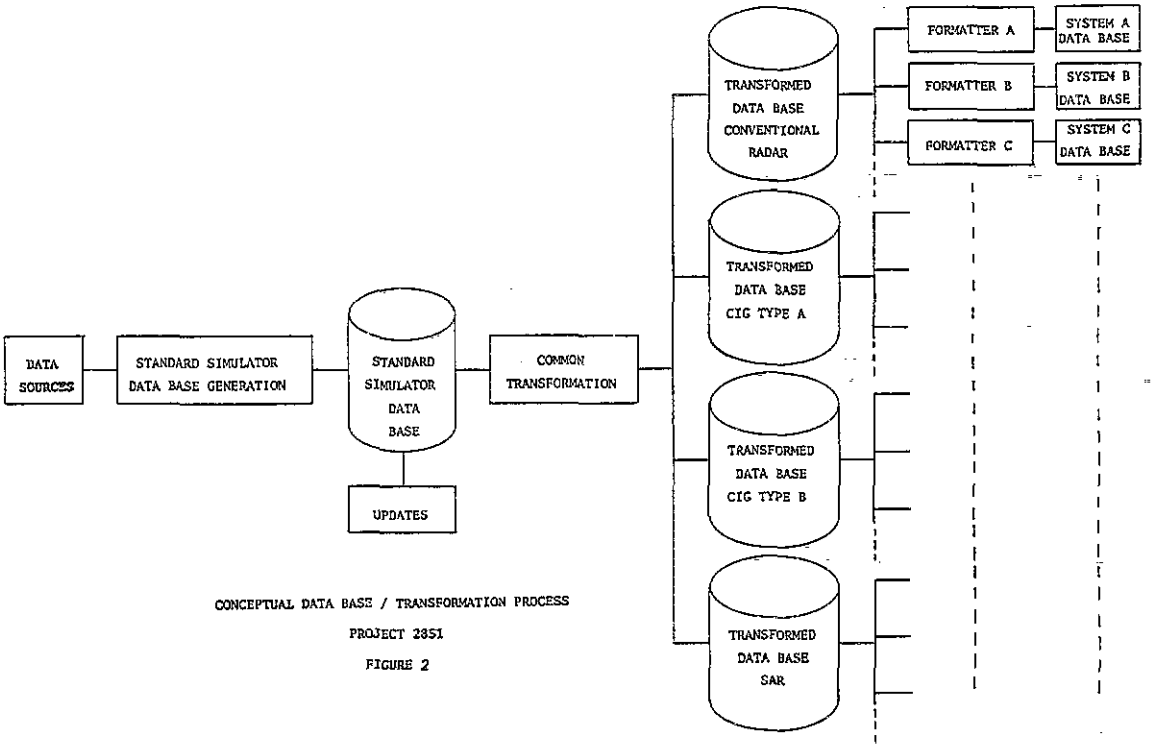
The standard simulator data base must meet the operational training needs of a wide variety of different requirements associated with Army, Navy, and Air Force simulator applications. Both cartographic and hydrographic data will need to be considered. The varied types of training place different kinds of requirements on the data base. These requirements range from very large areas (one million square nautical miles) with low to moderate detail to limited areas (hundreds of square nautical miles) with very high detail to some combination of these extremes. There are also requirements to support initial training, transition training, and continuation training, including mission rehearsal. Individual programs must be able to select and implement only what they need from the standard data base. Individual site updates or modifications will still be necessary in order to support individual mission needs, but these changes can be fed back to the central data base site so that all users can benefit.

The most significant data base requirements that need to be supported are world wide area of coverage and mission rehearsal. Mission rehearsal in particular will be a significant challenge since a ground truth, feature by feature representation of the earth's surface may be required for many simulator applications. Another major challenge will be the development and merging of highly detailed areas of real and synthetic data. The standard simulator data base must support enhancement of DLMS data, including manual enhancement, insertion of generic feature models, and addition of non-real world information using a process called synthetic breakup.[4]

Support Requirements.

Once a standard data base is created to meet the operational requirements, the need will exist to generate on-line simulator data bases i.e., develop data base transformation programs maintain configuration control, and update the data bases when new source information becomes available. Configuration management will be particularly important to insure data base availability for all simulator users and to avoid duplication of data base generation effort. Once a data base is generated for a particular geographic area, information on its availability, content and currency must be accessible to all simulator users.

A data base generation/transformation support



CONCEPTUAL DATA BASE / TRANSFORMATION PROCESS

PROJECT 2851

FIGURE 2

center will be needed to provide support for operational simulators and acquisition programs. Data bases for new areas will be generated and/or transformed in support of users and for test and deployment of new simulators. The magnitude of this task will vary continuously, depending on the numbers, types and sizes of areas needed. This center will have to modify and/or update previously generated areas based on revised source data and inputs from the field. There will be a continuing need to work with users and contractors developing new simulators to rapidly analyze and resolve problems as they arise. The center must support the test and evaluation activities of acquisition programs by supplying data, transforming data and resolving discrepancies in test results. Provisions for continuing research and development activities must be included to take advantage of new data base source materials and to maintain compatibility with new image generation techniques and transformation schemes. Finally it will be extremely important to keep the data base documentation current so that the data base content for any desired geographic area can immediately be determined.

PROJECT 2851 APPROACH

The data base generation/transformation process envisioned is illustrated in Figure 2. All applicable sources of topographic data will be utilized and converted to a common datum. The simulator data base will be generated by digitizing these cartographic, hydrographic, and photogrammetric sources and merging them with DLMS data. Generic models and synthetic data may also be used to enhance the DLMS. The final product of this process will be a standard simulator digital topographic data base. Provisions for updating this data base will be provided. At this stage the standard simulator data base shown in Figure 2 is not yet in a form ready to be directly loaded in a simulator. Because of the complexities of some of the transformation processes and the very lengthy time required for transformation, a goal has been established to identify the common transformation tasks and perform them once for all applications. It may be necessary to have individual transformation programs for a limited number of classes of applications e.g., conventional radar, synthetic aperture radar, CIG Type A, CIG Type B, etc. Ideally, transformed data bases will be in a format nearly ready for use by a particular simulator. In order to exactly match this transformed data base to a particular image generator, an adaptation/formatting program will be required for each simulator application. The goal is to maximize the common transformation processing and minimize the tasks remaining for the adaptation/formatting program. The feasibility and practicality of this approach remains a subject for further study.

This data base generation/transformation process is flexible enough to satisfy multiple purposes and many types of requirements. It permits a specific program to extract what is needed to satisfy its specific requirements. There are provisions for higher resolution data developed by a specific program to be added to the standard simulator data base and be available for subsequent users. Synthetic or non real world enhancements can be documented and separated from real world data. This scheme provides needed flexibility for individual programs but also forces individual data bases to be portable, thus reducing redundant modeling and generation efforts. By maintaining the standard simulator data base in a

partially transformed form, the complex, time consuming transformation processing can be reduced for each application. It is essential that the partially transformed data base be independent of any particular image generator design yet contain all information that might be utilized for a particular application. This approach does involve knowledge of simulator subsystem design to some extent, but this is a reasonable tradeoff considering the benefits. If there is a significant advancement in the state-of-the-art, the initial (common) transformation process can be modified to maintain compatibility with newer simulator subsystem designs.

The implementation plan for Project 2851 will employ a combination of in-house Government resources and contracts with industry. By utilizing this combined expertise, an optimized solution to the data base/transformation problems can be attained. The Government has knowledge of the requirements and problems experienced with past simulator systems developed by several manufacturers and the objectivity to keep the solution generic and not favor any one design approach. Industry has knowledge of simulator subsystem design and first hand experience with simulator data base design and development. The following six tasks describe the development strategy to be followed. A schedule is provided in Figure 3.

Task 1 - Data Collection and Technology Baseline Definition.

A comprehensive list of existing and planned DoD training simulators that require the use of digital topographic data for visual, sensor and radar image generation will be developed. For each simulator system, the data base requirements, transformation program requirements, data base and transformation software acquisition costs, and training requirements will be collected. A detailed analysis will be conducted to determine which requirements are common among the simulators, which are common for a particular training category, and which requirements are anticipated for future applications. In addition the simulator industry will be surveyed to determine what advancements in the state-of-the-art can be expected that would impact the form of specific simulator data bases. This task will provide the basic data and will establish the baseline from which the project development effort will evolve. Task 1 will result in a technical summary describing DoD simulator systems utilizing digital topographic data and, for each system, a description of the data base and transformation program requirements. Task 1 will be an in-house Government activity requiring the involvement of each of the three services and is scheduled to be a 9-month effort.

Task 2. Evaluation of Data Base Sources.

An evaluation and analysis of existing data base sources will be accomplished in parallel with the Task 1 activities. Existing sources will include Level 1, Level 2, and Level V DMA data as well as other digital, photogrammetric, and chart sources. In addition to the analysis of real world data sources, an analysis of data base alternatives e.g., generic data base, synthetically generated data bases, etc. will be accomplished. Task 2 is intended to be a front end analysis which will provide information in support of the later tasks of requirements definition, program methodology, and software development. Task 2 will result in a technical summary describing the utility, strong points, and weak points of existing data base sources as well as the feasibility of generating data bases from non-real world sources or by combining real world with non-real world features. Task 2 will be an in-house Government activity and is scheduled to be a 15-month effort.

Task 3 - Program Requirements Definition

A training evaluation will be accomplished to determine data base and transformation program requirements as a function of training requirements. A composite set of simulator data base requirements will be developed, based upon results of the training utility evaluation data collected in Task 1, and the experience of the tri-service working group participants. A major goal will be to define a process that does not stifle future technological innovation nor severely limit the use of those innovations. It will then be necessary to develop a data base generation concept to identify which functions should be accomplished during the simulator data base creation process, which functions should be accomplished by a common transformation program for each application i.e., visual, radar, or sensor, and which functions should be accomplished in a system-unique environment, i.e., the adaptation/formatting process. The data base generation concept will serve as the basis for defining transformation program commonality requirements and alternatives. Task 3 will result in a technical evaluation of the requirements for the engineering development that will follow in Task 4, and will be accomplished primarily by the tri-service working group, although a limited amount of contract work will be considered. Industry inputs will also be solicited at this time. Task 3 is scheduled to be a 6-month effort.

Task 4 - Program Methodology

Once the data base generation concept and a set of requirements for both the data base and the transformation programs are established, the program development strategy will be defined. This strategy will pursue the primary objectives of developing a DoD standard simulator data base and common transformation software. The task will involve defining a set of engineering development activities that will be directed toward the program objectives and will determine the means by which each activity will be approached e.g., contract versus in-house Government work, which service or laboratory, etc. Task 4 will be accomplished by the tri-service working group and will result in a detailed program plan defining engineering development activities to be accomplished and technical specifications for the development activities. Task 4 is scheduled to be 6-month effort.

Task 5 - Data Base and Transformation Program Development.

During Task 5, the activities defined by Task 4 will actually be accomplished by both in-house

and contract efforts. Specific work activities will include:

1. The development of simulator data base generation software.

2. The development of advanced, multi-application simulator transformation programs.

3. The generation of simulator prototype data base areas.

4. The evaluation of the prototype data base areas on various non-real time and real time simulator training devices.

5. The development of data base maintenance methods.

6. Detailed technical reports describing both the development activity itself and the actual test results.

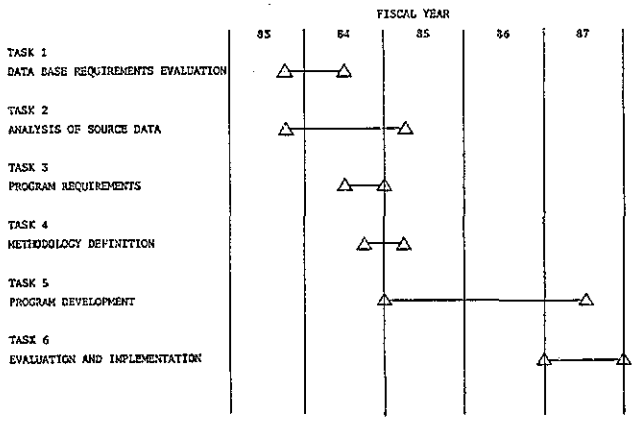
The development activity may be directed toward more than one specific approach and will permit government evaluation of several different alternatives. A wide variety of DoD agencies will play an active part throughout the development and follow-on testing. Testing of both the data base and transformation programs will include evaluations using both operational and in-house image processing systems i.e., DRLMS and CIG systems, reports describing both the development activity itself and the actual test results. Task 5 is scheduled to be a 30-month activity.

Task 6 - Final Evaluation and Implementation.

Once the data base and transformation program alternatives have been developed and testing completed, a final evaluation will be conducted by the tri-service working group from which an acceptable approach to data base generation and transformation will be selected. So that the selected approach can actually be utilized by each of the services, an implementation plan will be developed which will provide the means for an integrated DoD simulator data base generation capability. The final products of Task 6 will include a technical summary defining the approach selected for simulator data base generation, transformation, and maintenance, technical specifications defining the requirements for simulator transformation programs, a simulator data base generation capability including technical specifications defining the requirements for simulator data base content, and a final report with recommendations for DoD implementation. Task 6 is scheduled to be a 12-month effort.

SUPPORTING EFFORTS

Project 2851 will take advantage of a number of ongoing efforts to develop the standard data base and transformation software. These efforts have individually diverse goals, but all involve



PROJECT 2851 SCHEDULE
FIGURE 3

important considerations for data base standardization. Some of these efforts will be discussed in detail.

High Resolution Data Base

The High Resolution Data Base (HRDB)[5] also known as Level V, is an enhanced culture data base that is now available in prototype form from DMA. HRDB improvements over the earlier First Edition DLMS include the addition of roads, railroads, streams, airport lighting and buoys. Another major improvement is the addition of microdescriptors for some types of features. Microdescriptors provide additional information about the composition, or detailed makeup, of large homogenous DLMS features.

ASD is evaluating the HRDB prototype data to determine its ability to satisfy simulator data base requirements. The evaluation is making use of five small areas of prototype HRDB data which have been produced by DMA. The evaluation includes transformation of HRDB areas and generation of static CIG scenes. A dynamic demonstration of the CIG data bases on the C-130 visual system at Little Rock AFB is included along with a KC-135 radar evaluation at ASD. Results of the HRDB evaluation will be available by late 1983. HRDB or a derivative will likely be one of the major data sources for Project 2851.

Digital Multi-Use Feature File

The Digital Multi-Use Feature File (DMUFF)[6] is another new prototype culture digital data base from DMA. While this new data base currently exists only in the form of a draft specification, it probably represents the next step beyond the HRDB data base. The DMUFF is intended to support a number of different DMA digital products and thus various levels of data detail may be con-

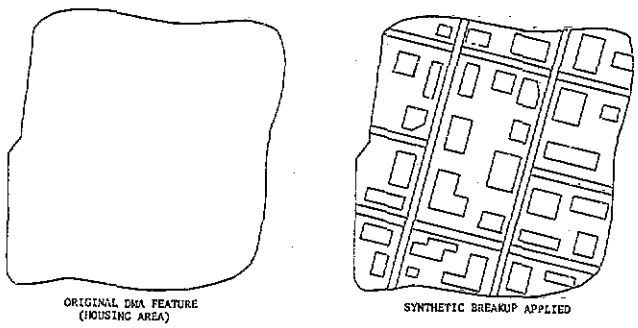
tained in the data base. The structure of the DMUFF enables storage and retrieval of many products over the same geographical area using common data elements to describe features applicable to these various products. Much of the impact of the DMUFF will affect only DMA internal procedures, although some format changes will be required. However users will likely receive better support for a wider range of applications, with some changes in data format. A number of new features and new feature descriptors will likely also be provided.

Synthetic Breakup

Another effort being pursued at ASD involves the development of a comprehensive synthetic breakup algorithm. This is a technique to statistically break up large homogeneous features as provided by DMA into representative distributions of their component parts. This technique is initially being developed to use the microdescriptor information provided in the HRDB data.

Figure 4 depicts the concept of the synthetic breakup process. On the left is the outline of a DMA feature which defines the boundary of a housing area. Using HRDB microdescriptor information supplied with this feature, the predominant street pattern can be determined and generated. Then a representative set of buildings can be distributed throughout the feature areas. The result is shown on the right.

Synthetic breakup is currently being developed as a preprocessing step prior to transformation. It is scheduled to be demonstrated at ASD using the HRDB prototype data in December 1983. In the future, this capability could be integrated with other transformation processes, and will certainly be included in the standard data base and transformation process where exact real world ground truth is not a strict requirement. Although synthetic breakup does result in data that is not in one-to-one correspondence with the real world, it has great value in providing clutter information for high resolution simulator applications.



SYNTHETIC BREAKUP
FIGURE 4

Quality Control

Over the years a number of deficiencies or anomalies have been discovered in the DMA data. Until recently, little emphasis was placed on the systematic correction of these problems; however, ASD has developed software to automatically detect nearly all occurrences of many of the types of errors which are particularly bothersome to simulator applications.[7] The software also automatically corrects a high percentage of these errors, and provides an interactive means of analysis and correction for the remaining errors. This software has been used successfully by both ASD and DMA to correct problems with culture data for several simulator programs.

These concepts of quality control must be applied and extended for Project 2851 to provide a more comprehensive analysis of both terrain and culture data. Similar techniques must be designed and applied to any standard data base product produced by Project 2851.

Cartographic Applications for Tactical and Strategic Systems

The Cartographic Applications for Tactical and Strategic Systems (CATSS) is an effort by the Air Force Rome Air Development Center (RADC) to formulate a comprehensive list of Air Force requirements for digital cartographic data. This effort will attempt to identify common requirements and minimize redundant development of digital cartographic products. Project 2851 personnel will keep informed of the results of the CATSS analysis and recommendations in order to insure compatibility as much as possible with identified common needs. The Project 2851 team will also inform the CATSS program personnel of any new requirements which are needed to support Project 2851.

SUMMARY

The objective of Project 2851 is to develop a DoD standard simulator data base and common transformation software that will be used for simulator training devices requiring the use of digital topographic data. The DoD standard simulator data base will provide a common source of digital topographic data that will be specifically compiled to meet training objectives and which minimizes the need to enhance DLMS data during the data base generation/transformation process for each individual simulator system. The common transformation software will attempt to reduce the amount of system unique software that will need to be developed for each simulator system. It will promote a greater degree of data base and software compatibility among the many DoD simulator systems. The results of the Project 2851 promise to be improved simulator training capability at reduced development, acquisition, and life cycle cost to the government.

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