COST-REDUCTION FROM SIMULATOR DATA BASE REUSE: FEASIBILITY OF REFORMATTING A-6/F-14 SIMULATOR DATA BASES FOR THE DOD STANDARD SIMULATOR DATA BASE PROJECT 2851

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ABSTRACT

Current estimates show that approximately one-thousand image generators are now in use for a variety of simulation applications. The cost of developing new data bases for these and future image generators is tremendous. One way to reduce up-front costs is to reuse existing simulator data bases rather than generate databases from scratch.

This paper describes the results of investigations undertaken by McDonnell Douglas Training Systems into the feasibility of reformatting three data bases into the Project 2851 Standard Simulator Data Base (SSDB) Interchange Format (SIF). These data bases, originally developed for the suite of A-6/E S/WIP and F-14D trainers, support visual, infrared, and radar simulations over large areas of the East and West coasts of the United States. They would be valuable and cost-effective additions to the Project 2851 repositories. We evaluated the following aspects of the A-6E S/WIP and F-14D data bases:

Levels of Detail	Feature Representations	Terrain Representations
Model Formats	Texture Representation	Infrared Attributes

We conclude that it is feasible to reformat terrain elevations, cultural features, models, and textures, given certain conditions on spatial resolution, thermal attribution, and texture representation. The results uncovered a need for minor changes to the SIF/HDI standard format.

ABOUT THE AUTHORS

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INTRODUCTION

A rough count of currently fielded flight simulators shows that there are over one-thousand computer image generator (CIG) systems used for a variety of aircrew training applications[1,2], with over one-half devoted to military applications. Although the data bases for many of these systems represent the same geographic areas, many were independently generated by CIG manufacturers. For example, at least four CIG manufacturers are represented at North Island NAS, and each manufacturer generated its own North Island data base. Such ab- initio generation of new CIG data bases does not capitalize on efforts put into development of prior data bases which depict the same territory.

In addition, current requirements for correlation are driving upward the already high cost of developing data bases for computer image generators:

- Correlation between Out-The-Window (OTW) visual systems and multiple sensor systems, such as infrared (IR) and radar.
- Correlation between multiple simulators with varying degrees of capability in their image generators.
- Correlation between image generator data bases, operator displays, and real time systems.

One way to reduce up-front costs is for the Department of Defense (DoD) to reuse existing simulator data bases to populate the repositories of the Standard Simulator Data Base Project 2851 (P2851).

AN OPPORTUNITY FOR REFORMATTING

McDonnell Douglas Training Systems (MDTS) has been under contract to develop common, sensor, and visual data bases for the A-6E System Weapons Integration Program (A-6) and F-14D (F-14) aircraft simulation systems. These data bases represent years of development effort and would be a valuable addition to the central repositories of the P2851 Standard Simulator Data Base (SSDB)[3] since they:

- Cover over 500,000 square miles of the United States
- Contain data for OTW visual and infrared and radar sensor simulations
- Contain enhanced areas for targets, airfields, radar, and visual areas of interest.

We describe solutions which are compatible with the SIF/HDI standard. Where appropriate, we recommend ways to improve the standard, preserving expended effort, and extending the SIF/HDI standard.

DESCRIPTION OF THE SOURCE DATA BASES

The A-6 and F-14 data bases represent three gaming areas within the United States, each referred to by its primary airfield. These data bases, illustrated in Figures 1 through 3, support OTW visual, infrared, and radar CIGs. The **WHIDBEY** data base, for the A-6 program, represents approximately 224,000 square nautical miles, mostly over Washington and Oregon. The **MIRAMAR** data base, for the F-14D program, represents approximately 72,000 square nautical miles of the southwestern United States. The **OCEANA** data base is shared by both programs and represents approximately 224,000 square nautical miles of the eastern United States.

Common Data Base Components

The Evans and Sutherland Corporation generated a common data base for each of the three gaming areas. Each data base is a collection of
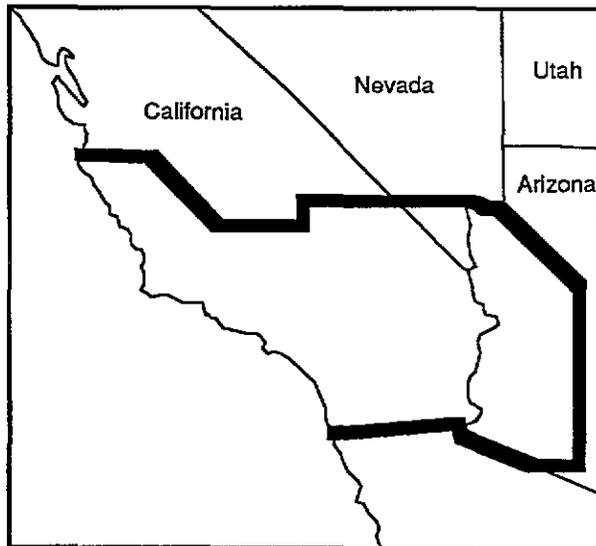
Figure 1. The A-6 Whidbey Data Base Gaming Area

Figure 3. The A-6/F-14 Oceana Data Base Gaming Area

Figure 2. The F-14 Miramar Data Base Gaming Area

component files which are in a proprietary format. The files contain data for visual and the Forward Looking Infrared (FLIR), and radar sensors. Depending on how they are compiled, these files may produce visual data bases, infrared data bases, or radar data bases. A common data base contains the following elements:

Objects – An object is a set of scene elements, polygons, and light strings, with fixed visual priority.

Models – Models are three-dimensional representations of features constructed from polygons and light points. They enhance the terrain and represent real-world and threat-world features. Models can be stationary or dynamic.

Texture – Visual texture provides altitude and velocity cues required for high-speed, low-level flight while minimizing the number of terrain and culture polygons. The visual texture has been specifically designed to support low-level flight. In both visual and radar simulation, texture also adds realism to models of buildings, ships, and aircraft by providing surfaces which appear real. The texture patterns, or texture maps, are constructed either algorithmically or from photographs.

Plane Features – Plane features are non-visible features which determine the visual priority among groups of visible features.

Terrain Representation – Two terrain representations, the result of several years of automated and manual modelling effort, are used to form the run-time data bases. The first is a 100-meter, gridded representation used to create radar run-time data bases.

849

The second is a coarse polygonalization of the earth's surface for visual and IR simulation. The polygonalized terrain has been forced to exactly match the gridded terrain at designated points to insure point correlation. While the automated parts of the processes could be repeated by starting with the original data and applying similar algorithms, the results of the manual efforts involved in supervising, evaluating, and editing will be lost if **both** representations are not retained.

Benchmark Features – Since the visual and radar run-time data bases use data of differing real-world accuracy for terrain representations, the terrain data may differ substantially. Benchmark features are used where a high degree of correlation between various sensors is required. The features specify *boundaries within which terrain elevations must exactly* correspond in both the visual and radar simulations. The tools which generate the radar run-time data base use benchmarks to ensure that the visual and radar data bases are correlated exactly in such areas by forcing the terrain within the benchmark areas to be equivalent in radar, visual, and FLIR data bases.

Run-Time Data Bases

An Evans & Sutherland ESIG-500 image generator processes and displays the contents of the visual and FLIR run-time data bases. The image generator uses its inputs and a set of data structures which model the run-time data base to determine the items to be displayed, their visual priority with respect to one another, and other image characteristics.

The MDTS Advanced Radar Image Generation System (ARIGS) radar simulator processes and displays the radar run-time data base to produce a simulated radar display. A run-time radar data base is a gridded data set which models the gaming area at a number of different resolutions. The radar data base formatter partitions the data base into square tiles, 256 posts on a side, with the posts spaced evenly in flat earth coordinates. Each post has data fields which specify elevation, reflectance, dispersion, directivity, and other attributes.

PROJECT 2851

Project 2851 is a Research and Development program chartered by the Joint Technical Coordinating Group for Training Systems and Devices. The objectives of the program are to reduce the costs of generating data bases for DoD training systems,

increase data base performance, and address problems of correlation within and between these systems. Cost reductions will be achieved by eliminating duplicate data base generation and redundant software development.

Project 2851 will result in a DoD Simulator Data Base Facility which will obtain standard Defense Mapping Agency products, externally generated simulation data bases, and other source material; archive and manage this data; and provide tailored data base products to DoD training simulators.

The SSDB Interchange Format (SIF)[4] will serve as the primary vehicle for sharing externally developed digital data bases across programs and services. Each time a new simulator program requires a data base, it will be able to access all relevant existing data bases maintained by Project 2851. Conversely, when a program has enhanced a data base, it will be able to send it to Project 2851 and make it available for other projects.

The SIF standard encompasses two formats, SIF for High- Detail Input/Output (SIF/HDI) and SIF for Distributed Processing (SIF/DP). The SIF/HDI format is the most appropriate format into which to place the A-6 and F-14 data bases, since their reuse *represents an exchange between an external simulator site and P2851.*

The second standard, SIF/DP, intended for distributed processing and supplementing the P2851 resources, allows data base exchanges in a format which is nearly identical to the internal P2851 format. It supplements the P2851 computational resources and facilities.

TRANSFORMATION OF THE DATA BASES INTO SIF/HDI FORMAT

The requirements of radar, visual, and infrared displays force the A-6/F-14 common data base to meet the conflicting needs of two different imaging systems:

- High resolution, low display rate radar system.
- Low resolution, high display rate visual and IR systems.

Levels of Detail

The conflicting requirements force two Levels Of Detail (LODs) for features and terrain. Since the

radar system has a low display rate, it can tolerate a high density data base which provides a very detailed representation of terrain and culture. Because the visual and IR systems have high display rates, which limit processing time, they require much less detail in their representation of the world.

Recommendation – The SIF representations of the common data bases should have two LODs. The two levels will meet the needs of both the high-resolution radar and the low-resolution visual communities and will preserve the effort already expended to meet these needs under the A-6 and F-14 projects.

Transfer of Terrain Representations

We have examined how to place data in the files, records, and fields of the National Imagery Transmission Format[5] (NITF), which the SIF Standard mandates for gridded terrain representations. There are no insurmountable problems in using this format to store gridded elevation data.

Recommendation – Because a significant amount of effort went into the generation of the two terrain representations, both representations should be retained: Use the 100-meter-gridded-elevation terrain for the best level of detail; use the polygonized terrain as areal features for the lesser level of detail. This combination provides the maximum possible value from the common data base, and meets the needs of a diverse user community.

Transfer of Culture/Feature Data

Each feature in the common data base is marked for applicability to visual, infrared (IR), and radar image generators. The Evans and Sutherland compilers use only those features marked for their targeted simulation. The visual and infrared compilers use only features marked for their use. The radar compiler selects the features marked for radar (often more detailed versions of the visual and IR features) and identifies the models which replace point features.

SIF/HDI Features – The SIF allows areal, linear, point, point-light, and point-lightstring features. It also allows two- and three- dimensional models both as replacements for features and as stand-alone features. Figure 4 shows a simplified model and feature placement for the SIF/HDI and a simplified diagram of the method by which SIF specifies a model which does not replace a feature.

Feature or Model Placement
(Model May Replace Feature)

Model Placement
(Stand-Alone Model)
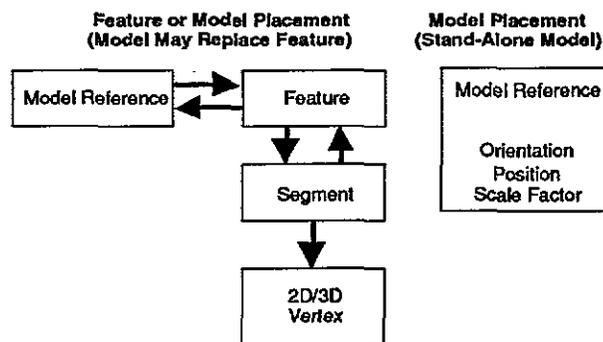
GP31-0181-4-V

Figure 4. Simplified Model and Feature Placement for SIF/HDI Format

It is feasible to reformat features from the A-6/F-14 common data base into the SIF/HDI format. The section on processing describes the software required to transfer features to SIF.

Transfer of Models

The static models in the common data base are three dimensional (3-D) polygonal representations of point features. They are high LOD representations of the models used for the visual run-time data bases. The dynamic and relocatable models are 3-D polygonal representations of aircraft, surface craft, missiles, and other moving and relocatable objects. They are constructed in the same way as are the static models, and are in the same format as static models.

We have found the transfer of models possible, but some amount of processing software must be created to accomplish the transfer. Since dynamic and relocatable models are constructed the same way as the static models, these models may also be transferred. Some missile models may require an axis exchange to place the Z axis along the direction of motion, to conform with the SIF model building standards.

Transfer of Texture

The common data base employs a generic texture type, called a modulation map, for both the OTW visual and FLIR displays. Modulation maps are texture element (texel) arrays in which the value of each texel determines a mix of two color values, a primary and a secondary, to form a resultant texture

color. The value associated with each texel is a modulation multiplier, a coefficient in the combination of the two texture colors:

$$
\begin{aligned}
\text{Resultant Color Value} &= \\
(1/255) \, * & \\
\left[\text{Texel\_Value} * \text{Primary\_Color\_Value} \right. & \\
+ & \\
(255 - \text{Texel\_Value}) \, * & \\
\left. \text{Secondary\_Color\_Value} \right. &
\end{aligned}
$$

For example, if a given texel has a value of 200, then the color for that texel is 200/255 times the primary color value plus (255-200)/255 times the value of the secondary color. In this way, up to 256 different colors could be present in a given texture pattern while using only two entries in a color LUT. Modulation maps are widely used throughout the common data base for terrain and cultural features such as grasslands, deserts, agricultural fields, broken clouds, urban areas, and airfield features.

General Use of Modulation Maps — Modulation maps are used by a wide variety of CIGs. However, in each installation of an image generator and display system, the patterns must be tuned to the characteristics of the actual system. For example, the primary and secondary color RGB values should be adjusted to accommodate the degree of contrast provided by a display system.

SIF Options for Texture — The SIF/HDI format has provisions for generic texture. According to the SIF standard[4]. the generic texture consists of "non-geospecific images for ... geographic areas...".

The NITF file types specified by SIF/HDI can easily contain texture data from the common data base. Modulation Maps can be stored by either of the two methods provided by SIF/HDI:

ACTUAL VALUES:

"the actual band value(s) at that texel position (e.g., the red, green, and blue intensity values)"

INDEX/LUT:

"an index into a look-up-table (LUT) which is defined in the Image Sub- Header File."

Recommendations — The Index/LUT method should be use to store modulation texture maps as SIF/HDI generic texture maps. Because it is most similar to a modulation map, it will occupy about two thirds less storage space than the other method, and it will be easier to convert back to the original modulation map structure. This method gives the user the opportunity to tune such a texture by modifying only two colors at a time, versus 256 or more.

The SIF standard be extended to allow storage of modulation patterns. Storage of these patterns would be fairly simple and would alleviate operational problems associated with re-deriving modulation maps from the Index/LUT maps.

Radar Texture

The SIF standard does not allow the inclusion of radar-specific texture patterns which represent features in the radar run-time data base. The SIF will hold neither the texture for the run-time data base nor will it hold a gridded representation of the data from which the patterns for the run-time data base can be derived.

The Radar Data Base Formatter, which produces the run-time data base, uses feature attributes to transform features into gridded representations which are conceptually very similar to SIF/HDI texture representations. The representations are arrays of data posts, evenly spaced in ground plane (X,Y) coordinates, with each data post representing the area surrounding it. Each data post contains a height representation and hardware-dependent codes for vertical/horizontal, reflectance, directivity, and dispersion. The SIF has no provisions for generic height, material, or use patterns.

Recommendations — The standard should be extended:

- The SMC/FDC pattern should also represent generic features.
- The gridded height representation should be extended to represent non- specific textured heights above terrain.

Coding of Infrared Attributes

The SIF cannot represent all the types of materials and material compositions provided in the common database. In the common database, an Extended Material Code describes the material composition of each model polygon. This code categorizes a material and its properties to a greater extent than do existing DFAD and Project 2851 codes. Examples

of the material codes from the A-6 and F-14 Data Base Design documents[6,7,8] are:

Code	Material	Material Characteristics
10	Aluminum	Dull, Thin
15	Aluminum	Dull, Thin
20	Aluminum	Polished, Thin
25	Aluminum	Polished, Thick
190	Leaves	Live

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Since there are many more material codes than the 14 valid Surface Material Category (SMC) Codes, the SIF format cannot represent the range of materials presented in the common database.

Recommendations – There are two choices for thermal attributes:

- If thermal models are available, derive the SIF attributes. Use either the existing Evans and Sutherland thermal model or another model.
- If no derived attribute can be made available, do not populate the thermal attribute fields, since the SIF does not provide for a sufficient representation of materials.

In addition, the SIF standard should be extended to better specify thermal attributes:

- Allow more than 14 material codes by defining material subtype fields.
- Explicitly define related FACS fields (living/dead, thick/thin, weathered, polished/rough, and others).
- Explicitly define FACS fields for thermal conductivity and specific heat.

A companion paper contains additional recommendations[9].

THE PROCESS OF REFORMATTING

The conversion process from the A-6/F-14 common data base to the SIF/HDI format is shown in Figure 5. The process flow is depicted in terms of the four major components in the process and their various conversion order dependencies:

- Textures
- Models
- Terrain
- Features

Since textures are independent of the other three A-6/F-14 common data base components, and are used by all the other components, they are first in the conversion process. Although models and terrain are mutually independent, both are dependent on textures which precede them in the process flow. Terrain is then the basis for features which are placed upon it. Not only do features derive their altitude from the terrain on which they are placed, but they are dependent on all three of the other common data base components in this process, and thus are the last item in the flow. The steps required to reformat any data base element are:

- Convert positions into latitude, longitude, and elevation
- Partition along lines of latitude and longitude
- Map common data base features into SIF/HDI features
- Provide model placements and replacements
- Place data into SIF/HDI files
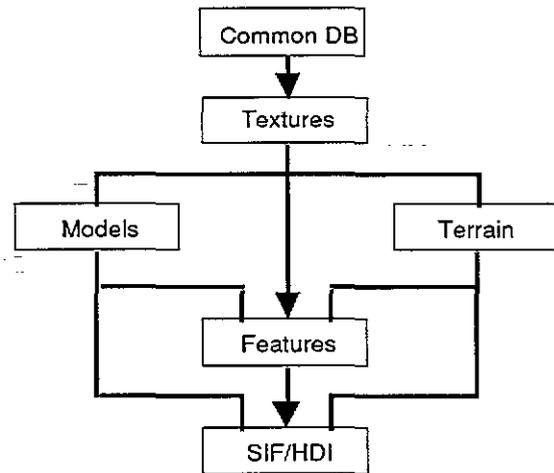
GP31-0181-5-V

Figure 5. Reformatting the A-6/F-14 Common Data Base Into SIF/HDI Format

ISSUES

The source data bases have several limitations which may require additional work for other applications:

- The high resolution terrain data have small discontinuities. Although these discontinuities are within DMA quality standards, they may create artifacts in high resolution radar simulations.

- There is a restricted set of models for point features
- There is a restricted set of heights for models
- Enhanced areas have sharply defined edges. (postage stamp effect).

CONCLUSIONS

Our investigations have resulted in the following conclusions:

1. It is feasible to reformat these elements from the A-6/F-14 common data bases.

   - Terrain elevations
   - Cultural features
   - Models
   - Textures

2. It is desirable to reformat these data bases since the simulation community will gain use of very large data bases containing many enhancements, and customers will save on database generation costs.

3. The process of reuse can be assisted by some minor changes to the SIF/HDI standard.

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REFERENCES

1. Warwick, Graham. "World Airline Simulator Status", Flight International, 8 - 14 April, 1992.

2. Warwick, Graham. "Simulated Action", Flight International, 28 October - 3 November, 1992.

3. Project 2851. Data Base Design Document (DBDD), Standard Simulator Data Base (SSDB). McLean, Virginia, Planning Research Corporation, for AFSC/ASD/YT, 1990.

4. Project 2851. Military Standard (draft) Standard Simulator Data Base (SSDB) Interchange Format (SIF) Design Standard. PRC, McLean, Virginia, 1993.

5. Defense Intelligence Agency. National Imagery Transmission Format (NITF), version 1.1. Arlington, Virginia: Defense Intelligence Agency, DIA/DM-1A, 1989.

6. Evans and Sutherland Simulation Division. Database Design Document, McDonnell Douglas Training Systems: Miramar. Evans & Sutherland, 1992.

7. Evans and Sutherland Simulation Division. Database Design Document, McDonnell Douglas Training Systems: Oceana. Evans & Sutherland, 1992.

8. Evans and Sutherland Simulation Division. Database Design Document, McDonnell Douglas Training Systems: Whidbey. Evans & Sutherland, 1992.

9. E. Bauman, B. Zvolanek, and D. Dillard. "Infrared Attributes for Project 2851 Standard Simulator Data Bases," Proceedings of the 15th I/ITSEC Conference, November 1993.