

CIG EDGE CONSERVATION EVALUATION AND APPLICATION
TO VISUAL FLIGHT SIMULATION

ERIC G. MONROE AND WARREN E. RICHESON
Air Force Human Resources Laboratory, Flying Training Division
Williams Air Force Base, Arizona

INTRODUCTION

This paper addresses a new approach to the visual scene presentation within a wide-angle optical mosaic display of computer-generated imagery, and a means of determining and analyzing the visual system processing and display capacities being utilized. An area of interest (AOI) presentation concentrates visual detail in that portion of the entire display to which the pilot's immediate attention is directed. The AOI transverses the display in real-time in coordination with the movement of the pilot's head. The result is a more efficient and effective utilization of system processing capacities which can be measured with the system's visual parameter monitor (VPM). An operational description of the VPM and AOI, together with an example of their integrated application, constitutes the body of this report.

VISUAL PARAMETER MONITOR (VPM)
DESCRIPTION

Computer Image Generation systems are relatively new in the simulation technology; and, therefore, a data bank of information needs to be compiled that would be useful for generating training and engineering specifications that will satisfy user requirements. Theoretically, the training requirement should drive the general systems specifications (for example, field-of-view requirements should be based on a specific training task for a given aircraft). The engineering specifications should then optimize the parameters that limit and/or define the visual processing potential of the system. The Visual Parameter Monitor (VPM) feature of the Advanced Simulator for Pilot Training (ASPT) provides a tool for both training researcher and engineer to investigate the Computer Image Generation (CIG) system hardware and hardware limiting parameters. The VPM can be applied in several CIG functional areas. Applications include an ability to conduct environment data base statistical analyses, experimental configuration definition, maintenance troubleshooting, real-time performance monitoring, and more accurate specification of future CIG system requirements. These functional areas can be categorized under two basic modes of CIG system operation: off-line and on-line. Real-time scene generation is accomplished in the on-line operational mode. Data base management operations and maintenance diagnostic operations are performed in the off-line operational mode.

In the on-line operational mode, the system accomplishes its real-time scene generation task in a serial computational manner. Data necessary to compute each scene is requested from the simulator computer each 1/30 second, and the corresponding scene is displayed approximately three television frame times (3/30 second) from the time of receiving new or extrapolated scene data. The CIG system is configured into three major equipment areas: The General Purpose (GP) computational system, the Special Purpose (SP) computational system, and the CRT electronics (Figure 1). Three time frames are utilized for processing the display data. The time phases are associated with the 33 millisecond frame time in which the data is processed in response to an updated viewpoint position and attitude. The equipment that performs these three time-phased tasks is referred to as Frame I, Frame II, and Frame III, respectively. While the Frame III hardware is producing the video signal which is used to present the picture being observed, Frame II is preparing information to be used for the picture to follow in the next television time frame period, and Frame I is working on data for the frame to follow that (Figure 2). Frame I operations are performed by the CIG system's GP dual-processor computer complex. During the first 33 milliseconds, this computer requests data from the simulator computer and performs frame rate processing functions necessary to generate data for the special-purpose hardware. The GP computer then processes these inputs to generate necessary data for Frame II operations and any output messages required to the maintenance console.

The following Frame I parameters are monitored by VPM:

- ACTIVE OBJECT COUNT
- POTENTIALLY ACTIVE OBJECT COUNT
- NUMBER OF ACTIVE MODELS
- NUMBER OF MODELS CHANGING PER FRAME TIME
- NUMBER OF LEVEL OF DETAIL CHANGES PER UNIT TIME
- NUMBER OF NEW MODELS TO BE ADDED TO ACTIVE ENVIRONMENTS/FRAME TIME
- DEPTH OF QUEUE OF NEW MODELS/FRAME TIME
- NUMBER OF MODELS THAT GO TO LEVEL OF DETAIL
- NUMBER OF FACES INTO FRAME II
- NUMBER OF OBJECTS PER CHANNEL

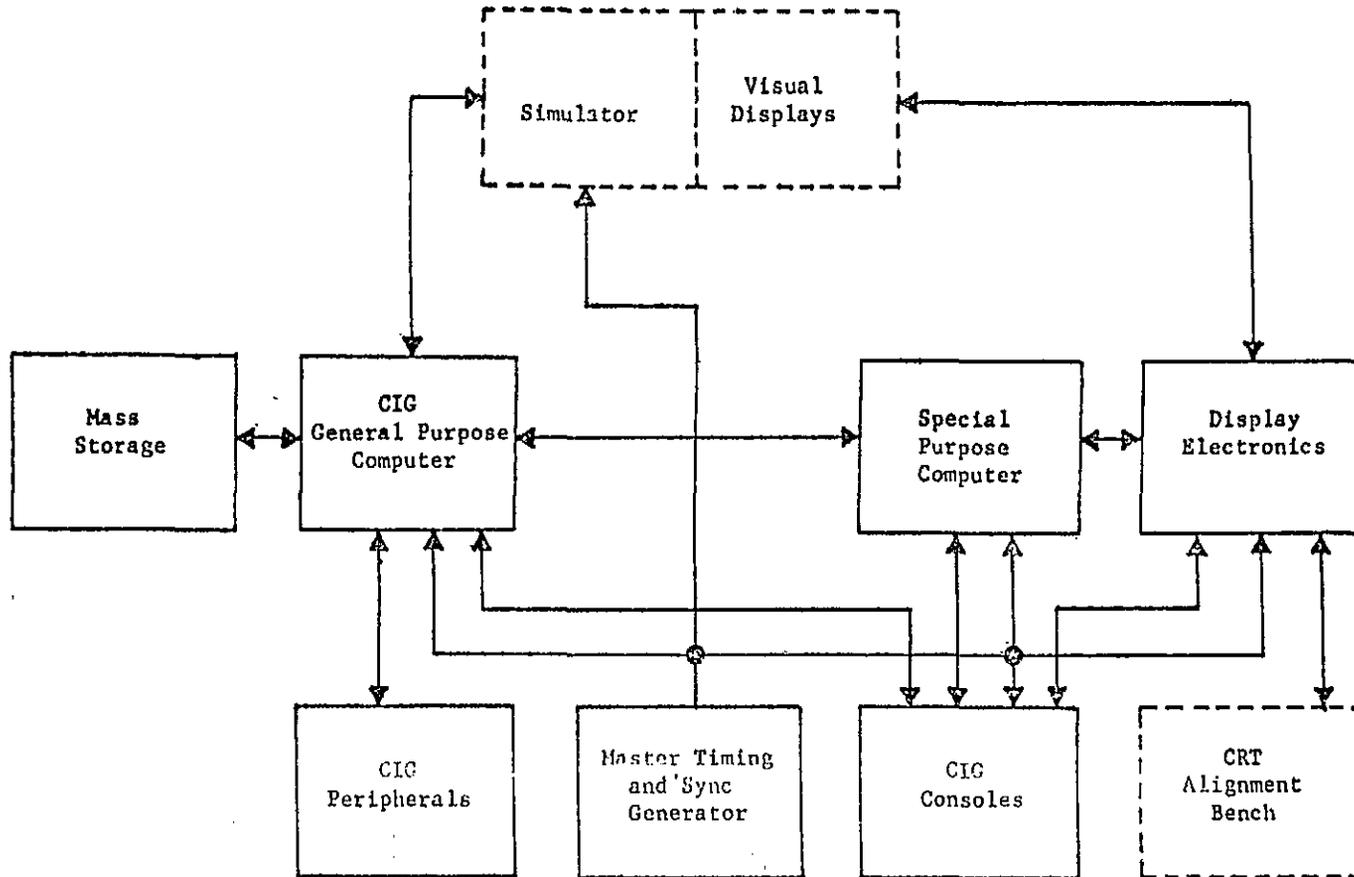


Figure 1. Computer Image Generation System

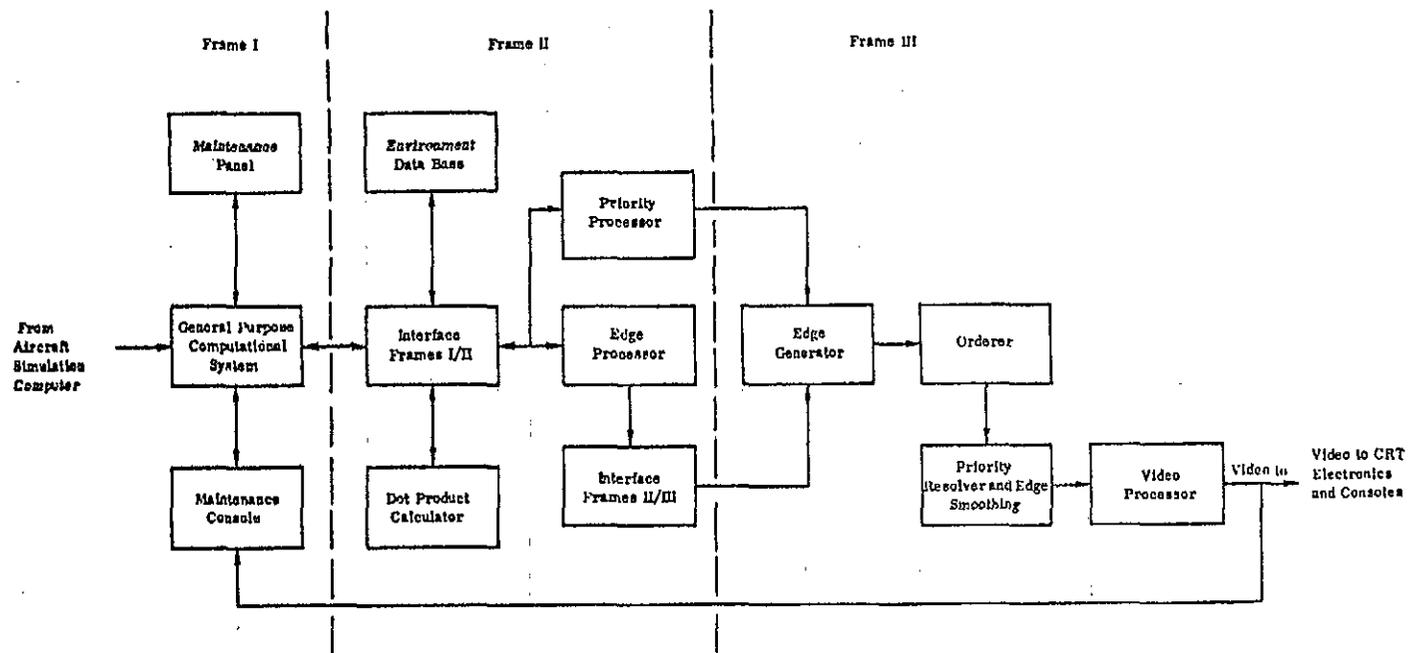


Figure 2. ASPT CIG System Functional Diagram

The calculation of the required edge and grey shade information is performed by the Frame II hardware. The major functions of this equipment are edge processing, fading and light brightness corrections, vector transformations, and priority processing.

The following Frame II parameters that are monitored include:

- FRAME II TOTAL EDGE COUNT (INTO EDGE PROCESSOR)
- FRAME III TOTAL EDGE COUNT (OUT OF EDGE PROCESSOR TO FRAME III)
- NUMBER OF ACTIVE FACES
- NUMBER OF EDGES/CHANNEL/FRAME

The Frame III hardware creates the video signals for the display projector by successively processing and accumulating data for each raster scan line. The data is accumulated for each raster scan line of each of the display channels, and then converted to video output signals. The major portions of the Frame III hardware are edge storage/edge generators, video/video storage, priority resolvers and video processors. The Frame III parameters that are monitored in real-time are:

- MAX EDGE CROSSINGS/SCAN LINE/FRAME
- NUMBER OF OBJECTS IN PRIORITY CONFLICT
- MAX NUMBER OF EDGE CROSSINGS/LINE/SYSTEM
- NUMBER OF EDGE CROSSINGS PER CHANNEL PER SELECTED LINE

In the off-line operational mode, the system performs data base and maintenance diagnostic operations. Data base diagnosis entails the debugging of operational data bases for training exercises. With the VPM, much of the trial and error procedure can be removed from the data base diagnostic sequence. The environmental data base for a CIG visual system is basically defined by straight line segments referred to as "edges." These straight line segments are combined to form two and three dimensional features of the environment. The organization and complexity of the environmental data base is constrained by CIG system hardware and software limiting parameters. It is essential that in specifying, developing, and modifying an environmental data base, the relationship between limiting parameters of the visual system and the desired data base be made available for analysis. The VPM provides a systematic means of categorizing and cataloging visual scenes generated from existing environmental data bases. Each visual scene cataloged can be recorded photographically and will include the extremes and statistics for each key system parameter. The software provides capabilities for both man-in-the-loop

and preprogrammed control of the flight pattern through the environment and allows the experimenter to preprogram the statistical parameters and values which will automatically stop the viewpoint motion to provide a visual scene freeze. A printout of a complete set of statistics for the frozen visual scene can then be provided by an operator command.

Catalogs can be developed which will logically categorize and catalog mission representative visual scenes from any environment. Individual catalogs would consist mainly of photographs accompanied by parameter statistics and descriptive information indicating the viewpoint, location, and attitude within the environment. Investigations with VPM would provide a means to analyze the relative and absolute relationships between the various CIG system limiting parameters as they relate to typical environmental data bases. This information would be extremely beneficial for specifying any CIG systems and their associated data base requirements.

Interaction with CIG parameter processing, both on-line and off-line, is via a continuous display on a high-speed, interactive display terminal CRT. This display is provided on an Infoton Vistar/GTX Display Terminal and permits the operator to select parameters with the terminal keyboard. Under keyboard control, the operator has the option of reading certain CIG limiting parameters or any special-purpose computer data bus quantities. Standard displays would include all or a selected subset of the Frame I, II, and III parameters previously listed. In addition to the CRT output, other mediums, such as the line printer, are available to the user of the VPM.

AREA-OF-INTEREST DESCRIPTION.

An area-of-interest projection in a wide-angle field-of-view (FOV) display in its pure form would present visual scene information only in the portion of the display in which the pilot is looking. The size of the AOI may vary, depending upon the application. For some applications, such as air-to-surface weapons delivery, certain visual information is necessary throughout the display. In cases such as this, a compromise can be made. Visual reference cues such as horizon and surface texture can be provided as peripheral cues throughout the display, whereas detailed visual information would only be displayed in the AOI.

The implementation of an AOI display for the ASPT was performed in a number of steps. The first step was to generate a number of fixed-size hoods to occlude the visual scene laying outside the desired FOV. (Figure 3)

These hoods were generated as the moving model of the environmental data base which was fixed to the viewpoint, aligned parallel to the longitudinal axis of the simulator aircraft and flew the same flight path. The next step was to generate computer software capable of creating a hood with any desired FOV in real-time via operator interaction. At this point, the data base features obscured by the hood were still being processed by the computer but were not seen in the display, since the hood had priority over all other objects. (Figure 4) It was now desirable to eliminate from processing those objects which did not intersect the FOV, in order to permit the concentration of objects and edges within the AOI. The hood, however, was still necessary to occlude the portion of a displayed object laying outside the AOI. The ideal situation would have been to eliminate the hood and truncate an object at the AOI boundaries; however, this would have involved hardware modifications requiring excessive lead time. Since an evaluation of the AOI concept had a pressing deadline, it was decided to postpone the incorporation of this refinement. Hardware and software modifications were also made at this time to make the hood independent of the environmental moving model and enable the AOI to be slewed throughout the cockpit display in real-time. Provision was then made to incorporate a helmet slaving device (HSD) in one of the simulator cockpits. (See Figures 5 and 6.) This system consists of a helmet with a pair of infrared sensors mounted on both sides, two sensor-surveying units, sight control unit and a control panel. Two sensor-surveying units are hard-mounted to the cockpit on each side and slightly to the rear of the pilot. These units generate infrared light beams which trigger signal pulses when they sweep over the helmet detectors. The sight control unit contains the digital circuitry for converting the detector pulse signals from the helmet sensors and sensor-surveying units into digital angles, and converting these angles into azimuth and elevation signals for controlling the line of sight of the AOI. Preliminary test operations indicated that a smooth, continuous movement of the hood without any jitter could be obtained with 0.5 degree filtering. Pilots also observed that it was extremely difficult to maintain their orientation without a horizon throughout the display. It was found that redefining the hood as a two-dimensional object allowed the horizon to have priority over the hood, with the hood still having priority over all other objects. Figure 7 exhibits this feature.

This configuration was used in an evaluation conducted in support of ASD/SD24 Simulator SPO Project 2360, Fighter/Attack Visual Simulation. The major objective of this evaluation was to determine the size of the

AOI required, in order to adequately perform air-to-surface weapons delivery. A second phase of this study is planned to evaluate the effect that peripheral cues (in addition to the horizon) will have on the size AOI required for adequate air-to-surface weapons delivery performance. Engineering modifications will be performed to permit operation in this phase without a hood and yet retain distinct boundaries of the AOI through the truncation of the portion of an object extraneous to the AOI. The peripheral cues would, of course, be shown throughout the display.

AN AOI APPLICATION

The basic premise for an AOI presentation in a wide-angle FOV-CIG display is to conserve system edge processing capacity by displaying more visual data base edges in the area to which the pilot's attention is directed, at the sacrifice of displaying fewer edges in the periphery. This results in a more efficient utilization of the system edge processing capacity and conserves resources by requiring less computer processing hardware than would be required by a full FOV display for a data base of given edge density. In other words, a system having a given edge processing capacity which could display a data base of given edge density with the full wide-angle FOV display could display a more detailed or denser data base with an AOI display. Since the density of the displayable data base is inversely proportional to the size of the AOI and the CIG system's costs are directly proportional to system edge capacity, considerable cost savings could be achieved utilizing this approach.

To effectively determine the efficiency of an AOI application, a means to measure the CIG visual system parameters for various configurations is required in order to make the necessary comparisons. The VPM, as previously described, provides a valuable tool for such a comprehensive investigation. Figures 8 and 9 are photographs taken from the exact same viewpoint (with two different size AOI's) of a CIG scene of two different edge densities. They serve to illustrate the potential application of the AOI and VPM concepts. Tables 1 and 2 list the counts for some of the CIG visual system parameters for Figures 8 and 9, respectively.

The AOI size for Figure 8 is 70° horizontal by 50° vertical, whereas Figure 9 has an AOI size of 50° horizontal by 30° vertical. As can be observed from the figures and tables, the scene in Figure 9 is denser than the scene in Figure 8. The AOI size for Figure 9 is less than half that of Figure 8 and its scene contains 1.7 times as many edges. Since the purpose of this paper is

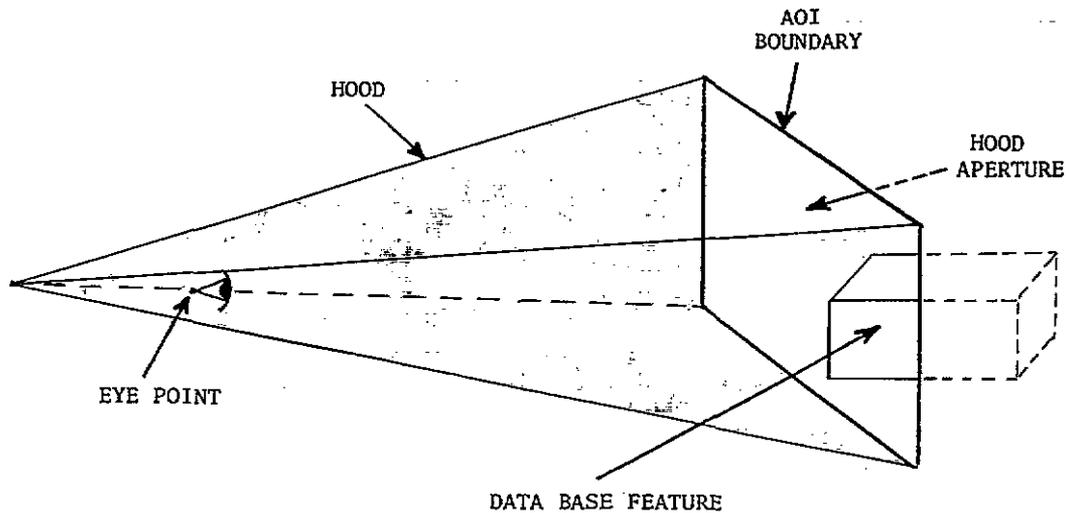


Figure 3. AOI Hood

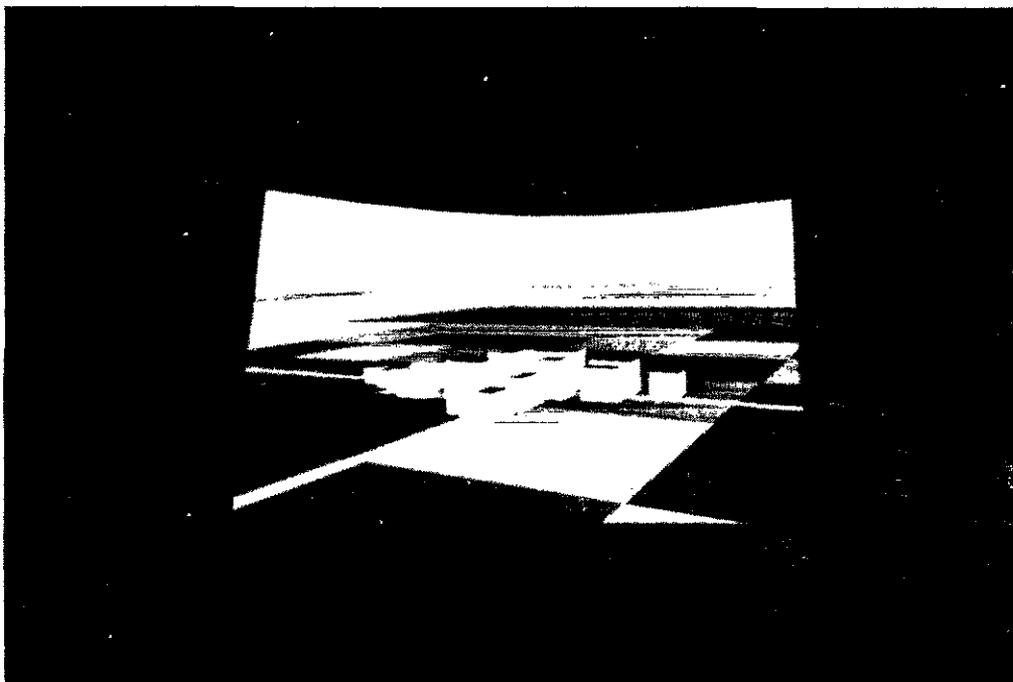


Figure 4. AOI Presentation with Hood

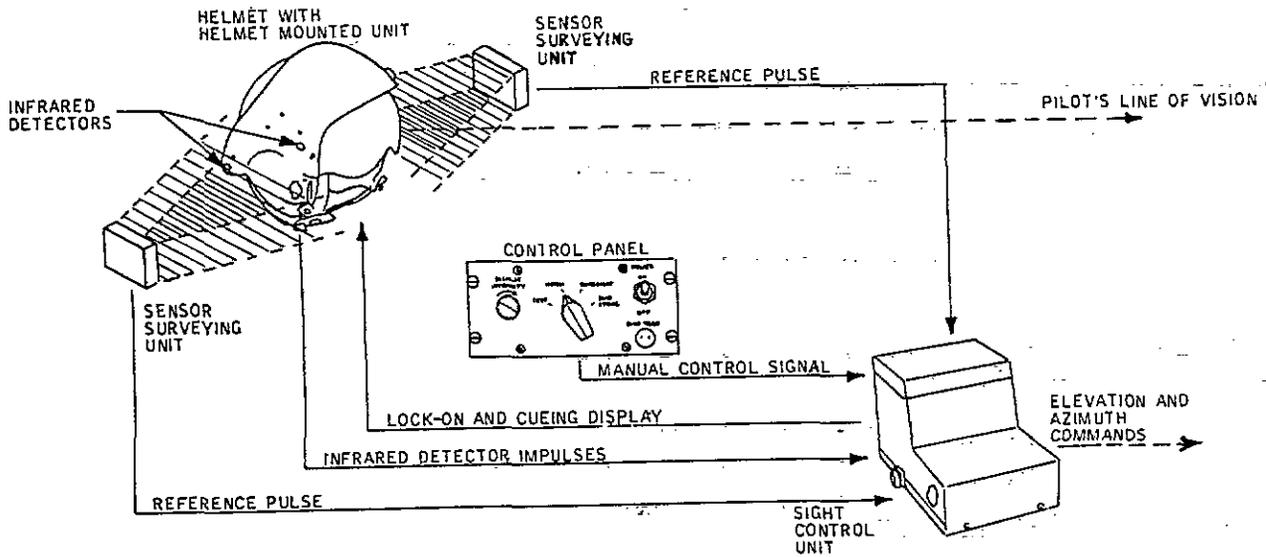


Figure 5. Helmet Slaving Device System

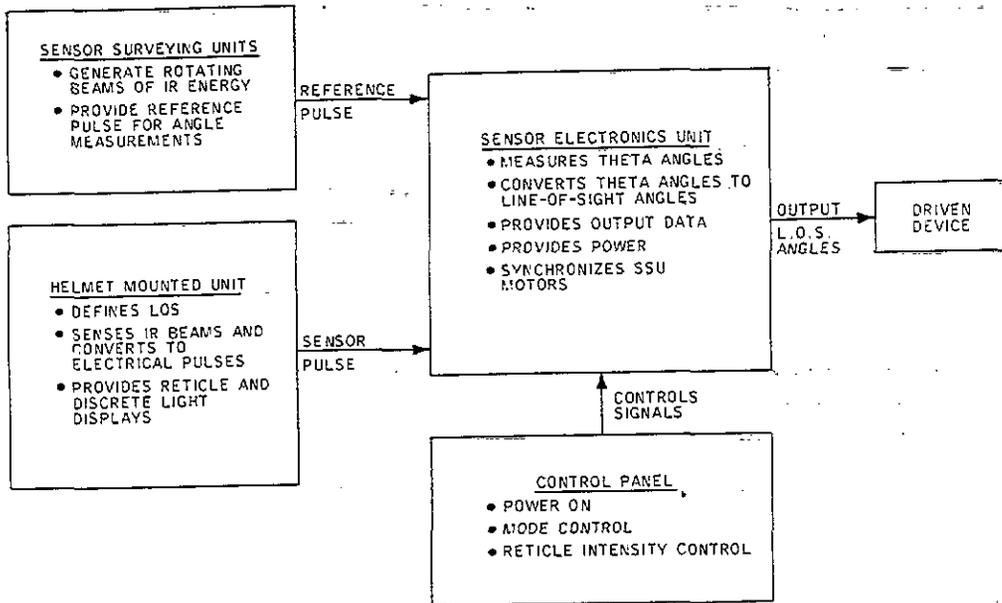


Figure 6. HSD Block Diagram

merely to acquaint the reader with the potential benefits that may accrue from the AOI and VPM concepts, no attempt will be made to derive any conclusions from the aforementioned data. To generate any such conclusions would require a much more detailed and sophisticated analysis, which is beyond the scope of this paper.

SUMMARY

Both the VPM and AOI present considerable resource conservation tools for CIG systems applications and design considerations. The

AOI concept provides a technique whereby the visual system capacity can be more efficiently utilized by dynamically concentrating image detail in the critical area of the display. Since CIG system costs are directly proportional to the system edge generation capacity, an AOI presentation offers a considerable cost saving potential. The VPM is a unique tool that provides the researcher with an exact definition of the visual systems configuration for any given experiment. It allows the modeler and the engineer access to parameters that influence data base requirements and special-purpose hardware designs.

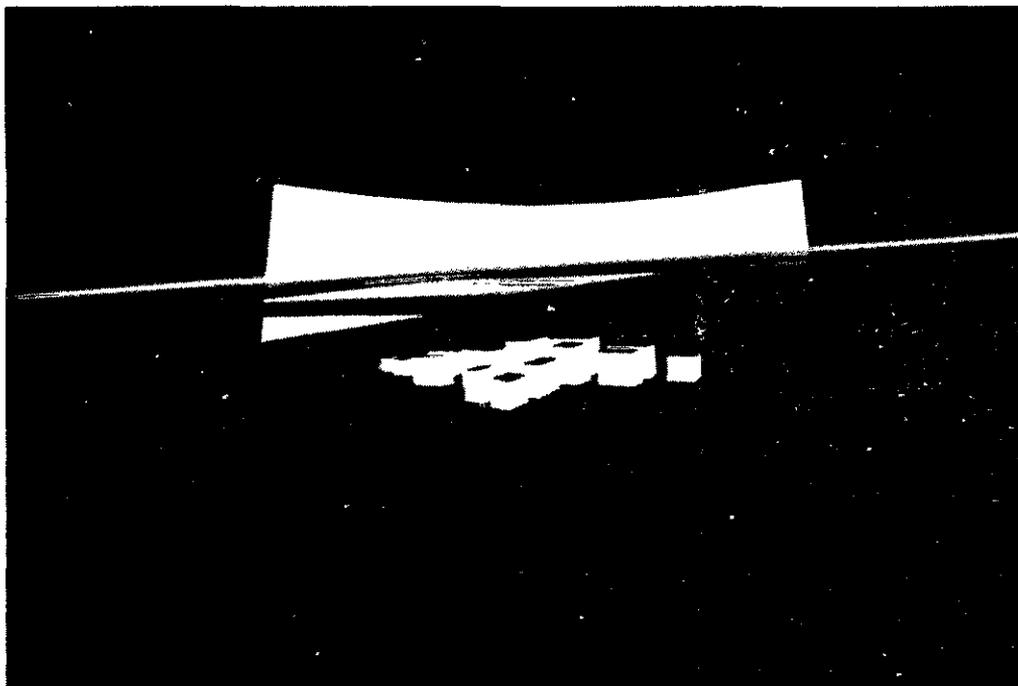


Figure 7. AOI Hood with Horizon

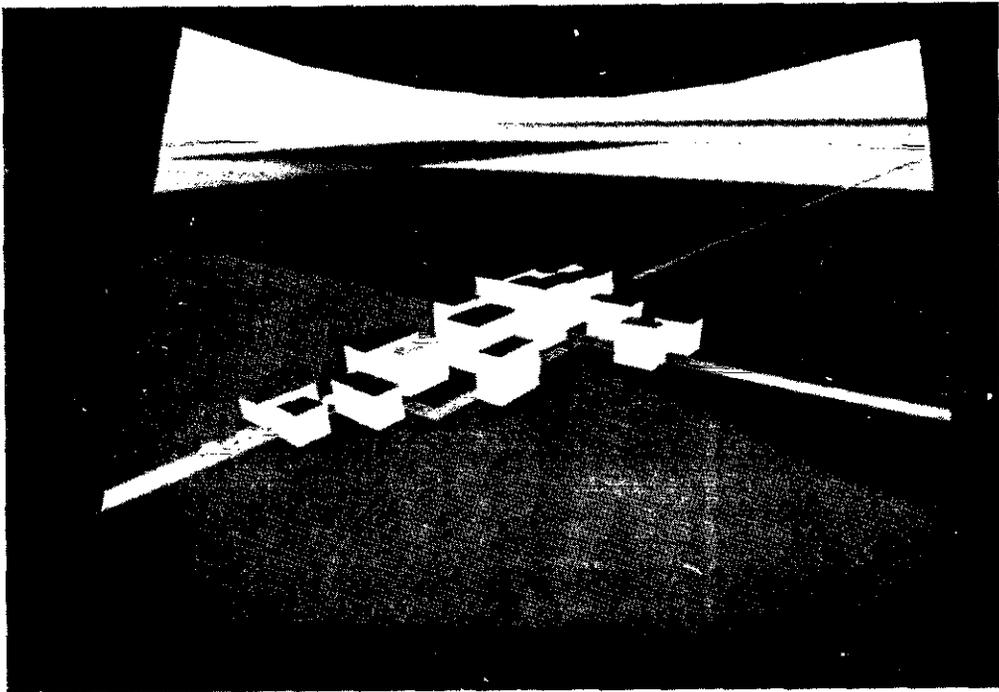


Figure 8. AOI Display (70° x 50°)

TABLE 1. VPM COUNTS FOR FIGURE 8

Potentially Active Models	64
Active Models	31
Potentially Active Objects	114
Active Objects	63
Frame II Edges	1991
Frame III Edges (Potentially Visible)	667

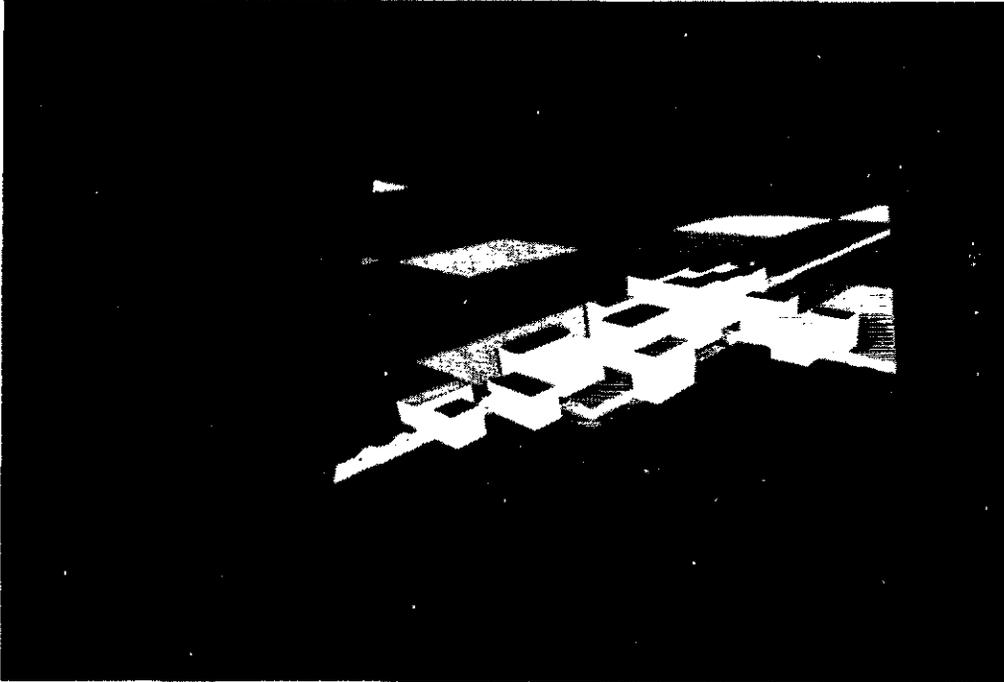


Figure 9. AOI Display (50° x 30°)

TABLE 2. VPM COUNTS FOR FIGURE 9

Potentially Active Models	66
Active Models	33
Potentially Active Objects	129
Active Objects	78
Frame II Edges	3236
Frame III Edges (Potentially Visible)	1134

ABOUT THE AUTHORS

MR. ERIC G. MONROE is the Visual Systems Engineer for the Flying Training Division of the U.S. Air Force Human Resources Laboratory (HRL) located at Williams Air Force Base, Arizona. In this capacity, he has prime responsibility for coordinating the activities of the software engineering personnel supporting the Visual System of the Advanced Simulator for Pilot Training. In addition, he has been the Project Engineer for numerous studies and has written several articles and technical reports on computer-generated imagery. Prior to joining HRL, Mr. Monroe worked in the computer simulation area with the Space Division of the General Electric Company and with the Combat Developments Command of the U.S. Army. Mr. Monroe holds the B.A., M.A., and M.S. degree in mathematics from Washington & Jefferson College, Duquesne University, and Stetson University.

MR. WARREN E. RICHESON is the Chief of the Systems Engineering Branch for the Air Force Human Resources Laboratory (HRL), Flying Training Division at Williams Air Force Base Arizona. He has been involved in real-time flight simulation systems for the past six years. Prior to joining HRL, he worked as a Mathematician with the Air Force Flight Dynamics Laboratory, University of Dayton Research Institute, TRV Systems, and General Electric Company. As Systems Engineering Branch Chief, he is responsible for the engineering development and operational support of the Flying Training Division's inventory of research systems and specifically involved in the management of the Advanced Simulator for Pilot Training (ASPT). He holds a B.S. degree in mathematics from West Virginia University and Graduate degrees from University of South Carolina and Notre Dame.