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ABSTRACT

Non-real-time feasibility was demonstrated in 1982 for a hybrid visual/sensor simulation approach which merges two technologies, Computer Generated Imagery (CGI) and Computer Synthesized Imagery (CSI) to form Computer Generated Synthesized Imagery (CGSI). This approach holds promise as a cost-effective, attainable method of providing real-time, high detail imagery for visual and/or other sensors, such as FLIR. Because of the high potential payoff from the development of this hybrid approach, a current program is aimed at demonstrating feasibility of this CGSI technology in real-time. CGSI uses a modular set of building blocks which may be configured to meet specific training and simulation requirements. The pipeline processor is the major element in a CGSI system. The pipelines accept control commands from the Field of View (FOV)/Controller module and input video data containing objects from the data base. The Pipeline Processor then outputs transformed objects to the scene-construction module and special-effects module. To control risks, a single pipeline is being fabricated and tested before the remaining modules and additional pipelines are fabricated. The feasibility demonstration of a single pipeline is scheduled for September 1983. The results of these tests will be included in the oral presentation at the conference, but unfortunately will not be available in time to meet the publication deadline for the written paper. A description of the test procedure is included here.

INTRODUCTION

Requirements

Sophistication of weapons systems is growing at a rapid pace. This sophistication takes many forms including increased operational capability through use of multiple sensor systems including FLIR (Forward Looking Infrared), Imaging RADAR, LLLTV (Low Light Level TV) in combination with out-the-window visual. Proper task loading is often necessary to train operators and maintain skills in the use of sophisticated weapon systems. The arguments against using operational assets include cost and safety. There is, therefore, a need for increased fidelity through simulation. Current approaches in visual and sensor simulation are inadequate for tactical training. Modelboard systems lack the ability to provide multispectral imagery, weapons effects, moving targets, large gaming areas, and wide fields of view. Present Computer Gener-

ated Imagery Systems lack scene content to support this type of training.

This paper addresses a new technique being developed to increase visual and sensor simulation system fidelity and capability. Honeywell's Systems and Research Center is presently under contract to the Naval Training Equipment Center and the Army Project Manager for Training Devices to develop this increase in visual system capability and fidelity. The system under development will merge the attributes of an optical disc technology approach, Computer Synthesized Imagery (CSI), and Computer Generated Imagery (CGI). CSI provides high quality imagery, but does not provide free movement within a gaming area. CGI provides the necessary freedom of movement, but with highly stylized or cartoonish imagery. This hybrid concept of Computer Generated Synthesized Imagery (CGSI) utilizes optical disc photographic imagery (CSI) overlayed onto a CGI background. In addition to

displaying individual objects in a scene, the system is capable of displaying groups of objects, imagery as seen from various sensors (e.g., FLIR and LLLTV) and adding smoke and other special effects. Initial non-real-time feasibility of this hybrid system has been demonstrated (1). Additional work is necessary and is being pursued to provide a real-time capability (i.e., a minimum update field rate of 60 Hz). Detailed design of a limited system was completed in April 1983 (2). CGSI uses a modular set of building blocks which may be configured to meet specific training and simulation requirements. The pipeline processor is the major element in a CGSI system. The pipeline processors change a stored image to scene conditions (screen coordinates) by changing image position, size, rotation, warp, and intensity. The Pipeline Processors then output transformed objects to the scene-construction module, pixel by pixel, based upon range. The pipelines will operate as single, large object processors; as multiple, small object processors; or as special effects processors.

A top-level system specification for each subsystem has been prepared. These specifications contained two key elements – performance and I/O requirements. After the specifications were reviewed and approved by both the Government and Honeywell, the detailed design effort began. Each subsystem was designed as a unit, with individualized hardware and software. This detailed design of the pipeline has been completed. The pipeline processor subsystem is the most complex subsystem. Therefore, to control risks, a single channel is being fabricated and tested before the remaining modules and additional pipelines are fabricated. The feasibility demonstration of a single pipeline was performed in early September 1983.

The CGSI system has been selected for a competitive fly-off to provide next generation visual and sensor simulation technology development for the U.S. Army. Technology being developed under this Army contract builds on a feasibility demonstration contract received from NAVTRAEQUIPCEN. This joint Navy/Army/Air Force effort will first demonstrate the real-time feasibility of the CGSI concept.

The U.S. Army requirements are for the AH-64 Apache helicopter combat mission simulator. Visual requirements encompass weapons effects and delivery, wide field of view displays to support nap-of-the-earth flight, multiple viewpoints, multiple sensors and multiple magnifications through a telescoping systems. The Apache requirements are felt to be one of the most demanding in the simulation industry today. The system described here could provide a capability to meet these requirements. The CGSI system has potential application for providing air-to-ground capability in the U.S. Navy's F/A-18 Hornet fighter/attack aircraft simulators and for filling low level contour training requirements on the CH-53 D/E and CH-46 helicopter simulators. One of the extremely attractive features of this approach is the potential for utilizing CGSI to retrofit existing CGI systems to increase performance. The Air Force's interest in this development results from the need for high fidelity simulation for air-to-ground attack missions. The Air Force Human Resource Laboratory (AFHRL) has provided funding support for the CGSI feasibility demonstration.

CGSI System Overview

The single pipeline is an integral part of the entire CGSI system. Therefore, a brief functional overview of a real-time CGSI system will be given here in order to provide understanding of the single pipeline in its proper context. Figure 1 is a functional overview of a real-time CGSI system. The functional blocks are separated into an off-line non-real-time data base construction module and a real-time processing system. A brief description of each module follows.

The data base consists of two very different types of data – the object library and the gaming area. The object library contains images of objects and surfaces in different spectral bands, and transmissivity masks of special effects. The gaming area data base provides the information necessary for placing the contents of the object library in the gaming area. The objects in the library may be either stationary or capable of movement. The vehicle simulation computations determine the locations and viewing
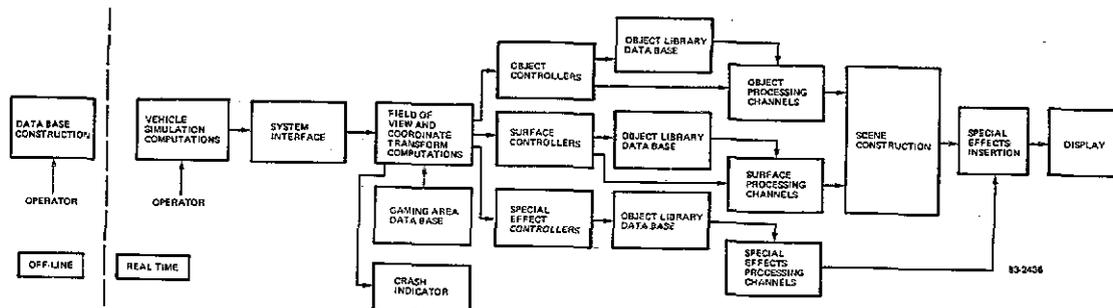

Figure 1. CGSI Functional Overview

direction of the visual or sensor system for the primary vehicle. The FOV processor determines the presence of objects, surfaces, and special effects in the scene under construction. The output of a transformation matrix converts the real-world coordinates to screen coordinates. The controllers fan out and process the control functions generated during the FOV computation. The processed control functions are passed to the object/surface/special effects processing channels. The object, surface, special effects (OSSE) library stores the images used to construct a scene. The controllers command the selected images which are passed to the processing channels. The individual processing channel pipelines process one object, surface or special effect per channel. All the processing channels operate in an identical manner. The object, surface, special effect channels change a stored image (normal perspective) to scene conditions (screen coordinates) by changing image, position, size, rotation and warp. Image intensity is modified based upon range and object type. The scene construction module takes the individual image from each processing channel, separates the image from the background, and assembles the scene based upon range. The high frequency edges generated by assembling a scene from individual images are smoothed, matching edge and internal frequencies. The translucent special effects are added after the generation of the scene. The special effects module adds the special effects based upon range. Special effects, such as smoke or dust, may occur ahead of or behind images in the scene. The intensity masks are stored in the object library and processed in the special effects processing channel.

OSSE Processing Channels (Pipelines)

In this section, the functional overview, shown in Figure 1, is expanded to provide a generic hardware overview for a single pipeline and scene construction and special effect components (Figure 2). The system is modular; a small system may contain only several OSSE processors and a large system may contain several hundred OSSE processors. It is the intent of this design to allow the system to produce any type of imagery, visual, IR, MMW (Millimeter Waves), SAR (Synthetic Aperture Radar), radar, etc. Current funding includes simulation of visual and IR imagery.

Each object, stored group of objects, surface or special effect is individually processed by an OSSE processor and used to construct a scene in the scene construction module and special effects module. Depending on the size of an OSSE image, the OSSE processors handle from 1 to 16 OSSEs per channel. In this section the path of an image (one full image or up to 16 small images) will be traced from the image storage media to the image display subsystem. The processing of the image
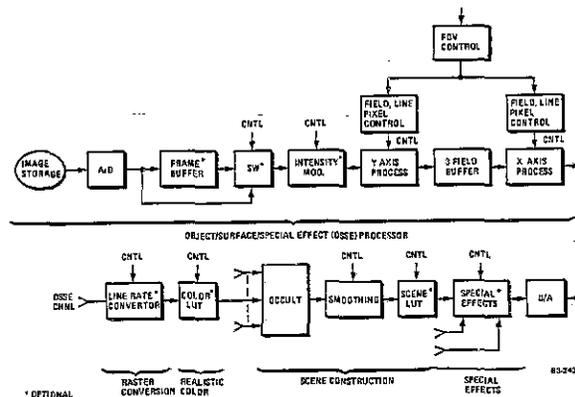

Figure 2. CGSI Configuration Elements

during its flow through the pipeline is under the control of a Field of View (FOV) controller. All OSSEs are processed in the same manner at the beginning. Depending on the function, major changes occur in the scene construction modules and special effects modules. Nontranslucent objects and surfaces (trees, rocks, bushes, tanks, etc.) are combined in the scene construction module. Realistic color or true color can be applied. Realistic color is generated via lookup tables and uses one pipeline, while true color uses three pipelines, one each for red, green and blue.

A/D Conversion. A high speed A/D module converts the analog video imagery to digital data. The module operates near 8 MHz and provides 8-bit, or 256 gray shade, output.

Frame Buffer. The frame buffer is controlled by the OSSE controller; it is used to store images that are not changing. This includes distant 2D objects and all surfaces and special effects. The warping process may compress data resulting in loss of resolution in the transmitted imagery if the image is rotated beyond 50 or 60 degrees. To limit rotations to + 45 degrees, a high speed memory design is used which can be accessed in both the X and Y axis. As a result, one image may be rotated a full 360 degrees without degradation through line and column memory access.

Frame Buffer Switch. The frame buffer switch allows the imagery to be held in the frame buffer for repeated use of 2D objects, surfaces and special effects. After an OSSE is stored in the frame buffer, the optical disc may be used to apply imagery to other channels. For dynamic 3D objects, the frame buffer allows the imagery to be taken directly from the optical disc without any delays. The frame buffer switch is controlled by the OSSE controller.

Intensity Modifier. The intensity modifier modifies the intensity of a scene in both global and local manners. Global changes use a LUT. As an example, these changes may be associated with range; that is, an object at a distance is more saturated and bluer than the same object at a very short range. Local modifiers multiply, on a real-time basis, each image pixel by an LUT value. The LUTs contents are a function of position within the frame. The intensity modifier introduces only pixel delays.

Y Axis Processing. The algorithm for distorting an object operates in two passes. Before explaining the Y axis functions, an overview of the warping function is presented. The warping algorithm contained in the pipeline operates in two passes; first the Y axis and then the X axis. The field microprocessor determines the offset (starting location), the magnification (change in line length) of the first line in each axis and selects the field memory buffers. The line microprocessor determines the delta offset and delta magnification of each line. The field microprocessor operates in a 16 millisecond cycle and the line microprocesor in a 63 microsecond cycle. The pixel processors operate on the pixel streams in a 100 nanosecond cycle or 10 MHz. During the first pass of the Y axis, each line in the row may be distorted in one or more of the following manners: Linear, perspective, curved, lens correction or multi-object (2).

Three Field Buffer. The three field buffer allows the Y axis processed image to be read into two field buffers, one for odd pixels and one for even pixels. The third field buffer allows either odd or even fields to be processed in the X axis processor.

X Axis Processing. The techniques used in the X axis could be identical to those used in the Y axis which includes the following functions: Linear, Perspective, Curved, Lens Correction, and Multi-Objects. In addition, for potential applications where perspective distortions in the real-world are not identical in the X and Y axis, the X axis processing could use algorithms which differ from the algorithms used in the Y axis. This case could occur with dome projection display systems or Synthetic Aperture Radar (SAR) imaging systems.

Line Rate Converter and Synchronizer. If the system requires other than 525 line video, a line rate converter changes the line rate of 525 lines to, for example, 875 or 1024 lines by changing the pixel clock rate. The line rate converter does not add lines or pixels; it only changes the rate at which the pixels are clocked in and out. In converting a 525 line system to 1024 line, for example, only 1/4 of the 1024 system is covered by a single 525 line input. The line rate converter

is a first-in/first-out buffer (FIFO) that synchronized and positions the 525 line, 10 MHz imagery to and within the 1024 line, 40 MHz imagery.

Realistic Color. The CGSI approach has been developed to provide monochrome; realistic color; or full, true-color capability (See Figure 3). True color is provided through the creation of three spectrally distinct data bases – each full-color photograph is digitized and stored separately using optical quality red, green and blue filters. When a full color image is displayed, the red, green and blue object images are independently processed and delivered to the red, green and blue channels of the color display system used. One can see that full color is bought for a price: three times as many processing channels are required relative to the number needed to generate a monochromatic version (e.g., IR) of the same object image. Near-perfect color is achievable in a much more economical manner. Most OSSEs contain only shades of one or two colors; i.e., consider green leaves, brown branches, blue water, camouflaged targets. Look-up table manipulation techniques permit the generation of realistic (as opposed to true) object and surface color on the basis of mapped gray-shade imagery. The realistic color approach allows the CGSI system to generate terrain, vegetation and object colors with one-third the processing required. To obtain realistic color, each object is stored as a spectrally mapped image. Associated with each image is a red, green and blue LUT conversion that assigns up to 256 colors to gray shade levels of the image. The 256 colors that are achievable may be 256 shades of one hue – for example, shades of green to create a high fidelity color image of a bush – or 256 distinct hues. The process is thus precisely controllable, and provides adequate color capability for combat mission training simulations.

SINGLE PIPELINE TEST PROCEDURE

A single CGSI pipeline design has been completed as described above. The feasibility demonstration is scheduled for September 1983. A test plan has been developed to verify the operation of this single pipeline and will be described here. The objectives of this demonstration are to verify the speed and accuracy of a single pipeline, to provide contractor in-plant testing of a single-pipeline, and to provide real-time warping of 2D objects and 3D objects for both the visual and IR spectral regions. Figure 4 gives a system block diagram for the single pipeline feasibility demonstration.

Measurements of speed will include both throughput lag and update rate. Figure 5 gives the nominal design timing for the CGSI systems. Throughput lag (transport time) is defined as the time between the receipt of positional informa-
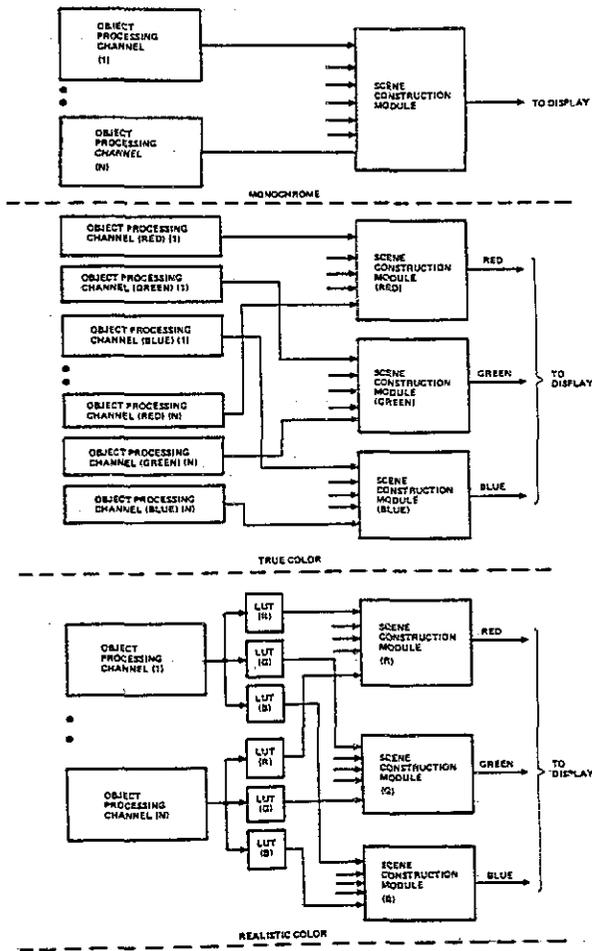
MONOCHROME

TRUE COLOR

REALISTIC COLOR

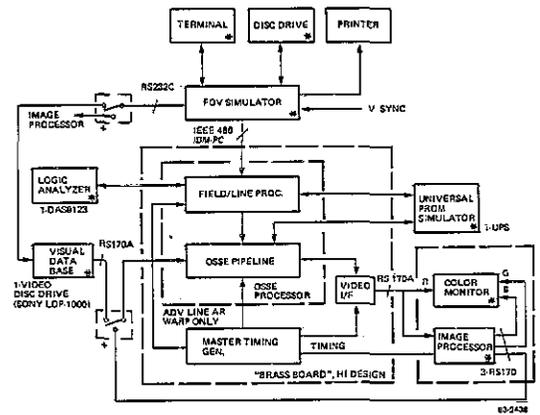Figure 3. Color Hardware Configuration

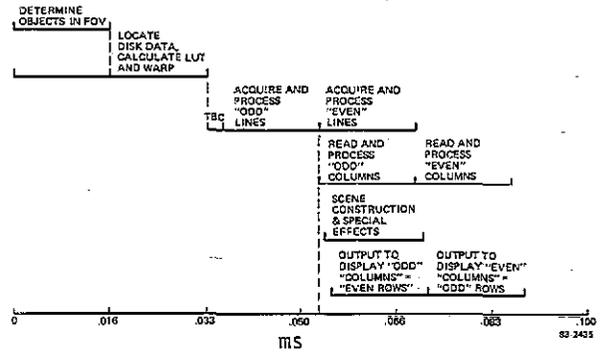

Figure 4. Single Pipeline Feasibility Demonstration

Figure 5. CGSI System Timing

tion from the vehicle simulation computer to the completion of the picture scan. Based on use of a specific test pattern, the delay from receipt of positional change information at the FOV computer to a change in output pixel value will be measured with a logic analyzer. Update rate is defined as the rate at which vehicular position may be changed. The design target update rate is 60 Hz. The operator will start the simulation, causing the object to be displayed and move. Motion will occur because the FOV simulator outputs coordinates to the "pipeline" via the IEEE 488 interface at a 60 Hz rate. Delta values will be applied at each update by the simulation program to make the object move on the screen. Proper rate of motion will be verified by having the image processor sample frames out of the pipeline. These frames will then be analyzed off-line to verify that the pixel(s) are in the expected location(s) for the particular frame sample times.

Measurements of accuracy will include both measurements of screen location and timing. Screen location is defined as the absolute location of the object within the FOV as expected from commands transmitted to pipeline by the FOV computer. The test object will be translated in x,y, magnified, compressed, and rotated independently and in combination. The output of the pipeline is fed back into the image processor (See Figure 4). The image processor will enable non-realtime simulated imagery to be compared to real time pipeline imagery such that the monitor will display the object in three colors as follows: R=pipeline modified object, G=image processor modified object, B=background. The image processor and trackball will be used in combination to find differences between these images. Differences will also show up obviously as yellow on the color monitor. All differences shall involve 1 pixel or less. The timing of an object relative to the horizontal sync signal shall be controlled to

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ensure object to object alignment at the scene construction module. The operator shall select an object which consists of a single pixel located in a known time slot on a known line. An oscilloscope shall be used on the pipeline output video to measure the location of the single output pixel relative to the line sync and the master sync.

The image stability will be tested. Image stability is defined as the constant location of an object from frame to frame in time. The operator will select an object to be sent through the pipeline. The image processor will be used to periodically sample a group of three frames. The image processor will be used off-line from the test with the pipeline to measure the location of the pixel matrix in each sample frame. The matrix location shall vary by no more than +/-1 pixel from the average (nominal) location across all of the sample frames. In addition to the above quantative tests, the following qualitative demonstrations will be observed. The image quality shall be photographic quality with minimum degradation resulting from processing. The capability of warping/displaying 2D and 3D

objects for both visual and IR will be observed. The capability to interface the pipeline to a video disc player will be demonstrated. Realistic motion of objects will be assessed.

SOURCE OF DIGITIZED IMAGERY
FOR A SINGLE PIPELINE

A point which may seem obvious to some, but is worthy of emphasis, is that a single pipeline can process any type of digitized data. It is immaterial what region of the spectrum (visual, IR, RADAR, MMW) is represented by the imagery or what the original source of the imagery was (real-world object, physical model of object, non-real-time CGI).

Current funding provides for simulation of visual and FLIR using the CGSI pipelines. Qualitative analysis indicates that other imaging sensors such as SAR and MMW could also be handled by CGSI pipelines.

Figure 6 emphasizes the fact that the source of the digitized imagery is variable. The CGSI pipeline can warp and properly inset any digitized image into a

Figure 6. CGSI Composite With Different Image Sources

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scene. Figure 6 is a CGSI synthesized composite scene which illustrates three alternatives. It shows a real helicopter image which has been properly inserted into the mid-ground of a forest scene. It is obvious that in the real-world, it will not always be possible to photograph target objects at close range from various aspect angles. One alternative is illustrated in the foreground. A model tank has been constructed, photographed, digitized and properly inserted into this same scene. In addition, computers are capable of generating highly detailed, realistic objects in non-real-time. This non-real-time CGI (computer generated imagery) could provide input to the CGSI pipelines as illustrated in the sky. The fixed wing aircraft is a non-real-time CGI image. In some cases, non-real-time CGI may provide a viable alternative for feeding a CGSI pipeline.

The critical point to emphasize here is that the single CGSI pipeline has been designed to be a highly flexible, modular building block for providing high fidelity visual and sensor simulation to meet a wide range of training simulation requirements.

MULTIPLE PIPELINE CONFIGURATIONS

As the CGSI concept moves into physical realization in a real-time demonstration, its application to real-time training visual and sensor systems become practical and advantageous. Such application

is clearly warranted whenever high object fidelity or high data base flexibility is required, although other instances of favorable application exist.

This CGSI development is unique for a research effort. Critical considerations are being designed into the system from the ground up. These include reliability, maintainability, integrated logistics support as well as development, production, and support cost issues. CGSI is being designed as a system that works and will continue to work in a cost effective manner in an actual training environment. This is an extremely ambitious undertaking. However, if these critical considerations are not designed into the system initially, extensive redesign would be necessary in order to provide a capability for answering real training problems in the field.

System Analysis. Based upon the identified training mission requirements, CGSI systems configuration development becomes an iterative sequence of refinements/trade-offs involving the various CGSI building blocks previously described. The elements to be considered in addition to the training mission requirements are considerations of reliability, maintainability, integrated logistics support as well as development, production and support cost issues. Table 1 gives a listing of CGSI system building blocks and the configuration rules for developing a large CGSI system.

Table 1. Configuring a CGSI System from Building Blocks

o	SELECT DATA SOURCE	1) VIDEO DISK 2) WRITE-ONCE VIDEO DISK 3) MAGNETIC STORAGE 4) GRAPHICS
o	SELECT PROCESSOR	1) OSSE 2) OSEE/W/TRUE PERSPECTIVE 3) GRAPHICS 4) CGI
o	MAKE 525 OR HIGHER RESOLUTION DECISION.	1) 10 MHZ, OR 2) 40 MHZ FOLLOW-ON CARDS (ADD LINE RATE CONVERTER)
o	MAKE B/W, TRUE VS REALISTIC COLOR DECISION	(ADD COLOR LOCK-UP TABLE (LUT))
o	IS ITERATIVE SCENE DEVELOPMENT REQUIRED?	(ADD ITERATIVE RANGE AND IMAGE MEMORIES)
o	IS CHANNEL IR, VISUAL B/W, OR VISUAL COLOR?	1) IR SMOOTHING, VISUAL SMOOTHING
o	SELECT NUMBER OF SPECIAL EFFECTS CHANNELS.	
o	CONFIGURE TIMING CONTROL, FIRMWARE, AND SOFTWARE TO MATCH.	

These trade-offs take two forms: 1) balancing training effectiveness versus cost, and 2) trading off technically limiting parameters to achieve optimum system performance. The training effectiveness trades are primarily related to number of OSSE channels required. When the training mission analysis has defined the *characteristics* and *count* of the objects to be presented, an obvious but simplistic approach to configuration would be to provide a channel per object. This, however, would produce an excessively large and costly system when alternatives exist with either no or minimal training impact. The number of OSSE channels required can be traded off against: 1) Offline development of composite scene views (clusters), 2) On-line iterative composite scene construction, 3) Area of Interest (AOI) displays, multiple resolution displays, 4) Realistic versus true color. (True color channels can be mixed with realistic channels if required for selected critical objects), 5) Training Cue Fidelity (This trade area is the most subjective but provides the most opportunity for ingenuity of approach), 6) Availability (For very large visual systems, system reliability becomes a training issue because of significant failure rates and/or extended repair times). Numerous alternative implementations and trades exist beyond these six in configuring a CGSI system. Trade alternatives exist in the purely technical realm also. An example is transport delay/update time. While the nominal transport delay of an OSSE process is related to a 512 X 512 image area, smaller image definition (say 256 X 256) will yield shorter transport delays by reducing the field processing time.

As an example, a CGSI configuration for a small visual system could provide potential applications for periscope training or hand-held missile or gunnery applications. Figure 7 shows a non-real-time CGSI scene of a view thru a periscope which could be provided in real-time by a small CGSI configuration. Figure 8 depicts a CGSI configuration capable of providing this image. Figure 9 shows a non-real-time CGSI scene of a AH-64 flying among the trees which could be provided in real-time by a large, robust CGSI configuration. Figure 10 depicts a CGSI configuration capable of providing this imagery level with all sensors supported for team training.

Design. The system analysis trades result in specific design requirements related to configuration. In assembling the required configuration from the CGSI building blocks, the modularity and configurability of the CGSI components together with standardized inter-card and inter-channel interface minimize new design. Correlated hardware, software and firmware components also ease the configuration process. Despite this modularity,

every new application will require unique responses.

Life Cycle Support. A key element of any trainer application is the life cycle support requirements of the system. This normally includes maintenance and spare issues. Increasingly, especially for software intensive applications, this has meant the enhancement or redirection of a trainer for new training requirements related to new tactics, new equipment (Avionics, Visionic Weapons Systems), and new personnel qualifications. Historically, visual systems have had extensive data base maintenance costs and infrequent but extensive hardware/software upgrades. CGSI promises significant improvements in all of these areas: 1) Maintenance – On-line BITE, and extensive isolation are included. 2) Spares – Few card types minimize replacement cost as well as lowering stores inventory. 3) New Training Requirements – Common building blocks permit multiple use of CGSI systems and
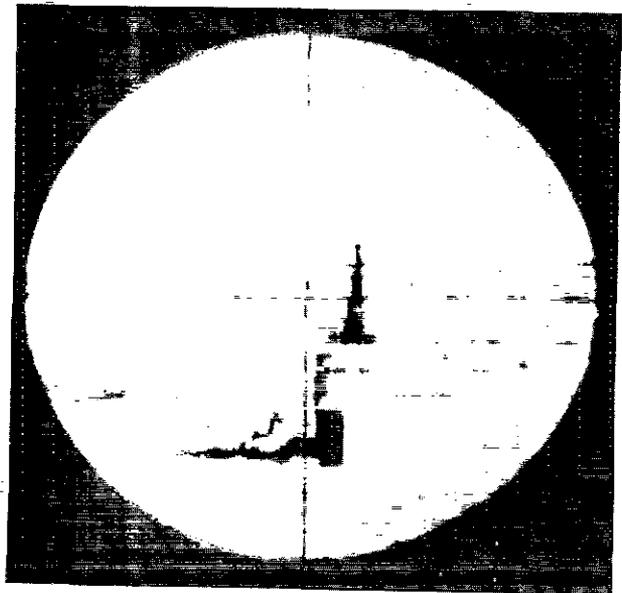

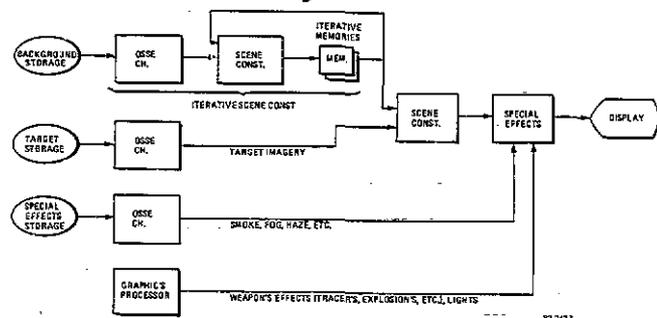Figure 7. CGSI Simulated Periscope Image

Figure 8. Small CGSI Configuration
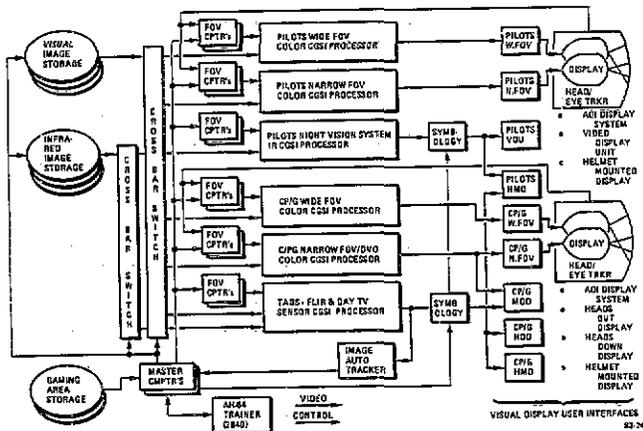
Figure 9. CGSI AH-64 Simulated Image

Figure 10. Large CGSI Configuration

incremental expansion to higher fidelity simulation. 4) Data Base Maintenance – Rapid specific area simulations through Defense Mapping Agency (DMA) data and straight forward data definition. Rapid target compliment updates are accomplished through actual imagery equipment for replacement applications or the addition of similar like components for new applications.

Adaptability. Beyond the new visual trainer application, CGSI is adaptable to a wide range of trainer and simulator applications. 1) Stimulators – Stimulation of operational equipment or equipment under evaluation is made possible by insertion of high fidelity video stream data to trackers. 2) Part Task Trainers – A modular approach provides limited simulation applications for limited training

goals. 3) Team tactics trainers – Systems providing coordination training involving multiple vehicles and/or ground personnel are easily configured. 4) Existing CGI visual retrofit – Typical CGI systems of today exhibit inadequate target fidelity and very limited background fidelity or a serious compromise of both. CGSI can be used to supplement such systems requiring higher fidelity.

CONCLUSION

CGSI is a viable approach to visual and/or sensor simulation in multiple applications ranging from the very small to the extremely large. It is clearly warranted when high object fidelity and/or high data base flexibility is required. It can readily support multiple sensors in integrated operation including special effects from multiple viewpoints. It is capable of providing specific area simulations with full freedom of motion for both own ship friendly vehicle and hostile targets, and supports Trackers and Weapons, with high Gaming area flexibility and large environment variations. The next critical milestone in this CGSI development is the demonstration of a limited multiple pipeline configuration (4 pipelines) integrated with all of the modules outlined in the block diagram in Figure 1. This demonstration is scheduled for April 1984.

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Ms. Dorothy M. Baldwin obtained her M.A. in Physics from Kent State University in 1968 and her B.A. in Physics from Hartwick College in 1965. Her 15 years of professional experience have been in government and academia. Her 6 years at Naval Training Equipment Center includes work on the 360 degree laser scan display system, the helmet mounted display system, and the annular projection system. Her current assignments include: Principal Investigator on the Multi-Spectral Image Simulation Project and Simulation of Advanced Sensors Project.

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Mr. Ted Dillingham obtained his B.S. in engineering from the California Institute of Technology in 1969. In his 14 years in the aerospace industry, he has experience in areas ranging from space instrumentation for Pioneer and Viking to advanced electro-optical weapons sensors. Mr. Dillingham has managed, developed, and tested key elements of military trainers ranging from the Air Force's T45 Undergraduate Navigator Training System to Navy's Fleet Ballistic Missile Sonar Operational Trainer. Mr. Dillingham is currently responsible for new technology applications at Honeywell's Training and Control Systems Operations and is the engineering manager for the VSCDP Project.