DIGITAL PROCESSING OF COLOR PHOTOGRAPHY

FOR VISUAL SIMULATION

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ABSTRACT

This paper describes the full color out-the-window visual system simualtor for the Navy's A7E Weapons System Trainer (WST), based on the Vought - developed Computer Animated Photographic Terrain View (CAPTV) concept. The system has excellent scene realism due to its real-world photographic data base. Any geographic area can be 'flown over' in the simulator with virtually no restrictions on aircraft attitude, position, altitude, heading or velocity. The flyspace can be increased indefinitely by additions to the terrain library. The display field of view is modularly expandable up to nearly the full encircling sphere while maintaining resolution of all parts of the scene.

I. INTRODUCTION

The need to provide scene realism in Visual Systems for flight simulators is well recognized. To this end, real world imagery is used in Vought developed Computer Animated Photographic Terrain View (CAPTV) Concept. The first successful CAPTV system (1) employed monochrome aerial photographs in a large random access video data base, which, through computer processing, provided smooth high detail simulated visual motion cues to the pilot trainee. This paper describes the follow-on effort at Vought to provide a full color out-the-window visual system for the Navy's A-7E Weapon System Trainer.

a given fixed scene, the computer is fetching a new appropriate view to be used as an overlay substitute. The new view is selected by a sophisticated prediction scheme that determines when the present photo must be discarded in favor of a new photo. It is important to understand that the transformation process does not cause unrealistic distortions of the viewed scene. The key to CAPTV lies in its unique capability to make one fixed photo serve in a dynamic translation situation long enough to fetch another view and incidentally perform many other functions as well.

II. CAPTV CONCEPT

The basic CAPTV concept assumes an array of still photographs taken from an airplane that covers the gaming area defined by pilot training requirements. Photographs are taken at regular intervals along straight and/or cross tracks. These photos are scanned, formatted, and stored in a bulk storage device. As the pilot 'flies' through these photos using controls similar to the ones on the cockpit panels, they are retrieved from the storage medium for display. At any given instant, knowing the pilot's eyepoint in space, the photo in the database nearest his location is stretched, skewed, rotated and trans-lated in a piece-wise continuous mathematical transformation such that the transformed photo would overlay a different photo taken from the pilot's eyepoint (Fig. 1). This process is a continuous one each frame time under computer control and allows the introduction of smooth translation into a basically still picture set for any direction of travel through that set. During the period in which motion is taking place using

III. OFF-LINE IMAGE GENERATION

The off-line image generation of the color Visual System is used to develop the data for the playback system. The image generation consists of the following subsystems.

(a) Aerial Camera

To provide for the 360° of azimuth coverage and 100° of elevation (with high resolution throughout), a special camera (Fig. 2) incorporating seven lenses with associated mirrors has been fabricated. A typical exposure on a 9" color film is shown in Fig. 3 (actual photographs used in the simulation are in color). Six lenses capture the oblique views and the central lens covers the straight down vertical view. The gaming area is partitioned to contain a large number of 'eyepoints' distributed in several altitudes in several straight and cross tracks. The photography density varies inversely with altitude to provide the required coverage for smooth transition from scene to scene. Objects
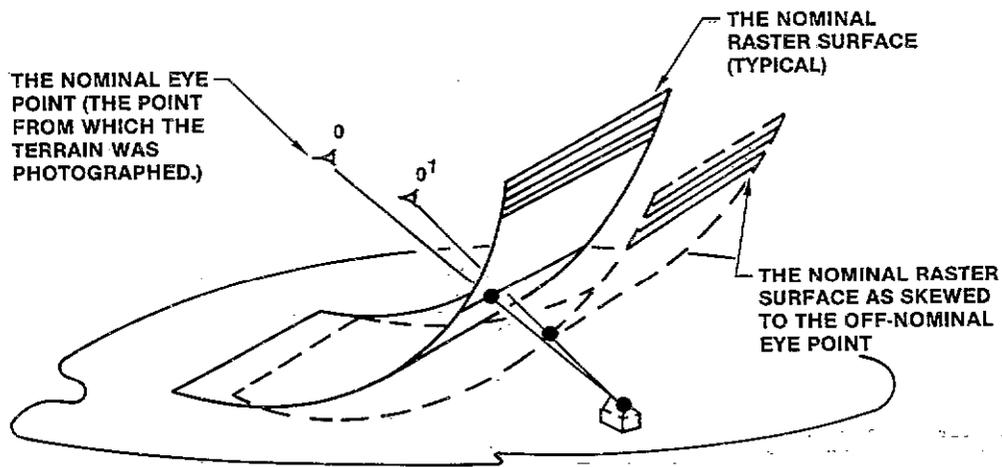
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THE NOMINAL EYE
POINT (THE POINT
FROM WHICH THE
TERRAIN WAS
PHOTOGRAPHED.)

THE NOMINAL
RASTER SURFACE
(TYPICAL)

0

0^1

THE NOMINAL RASTER
SURFACE AS SKEWED
TO THE OFF-NOMINAL
EYE POINT

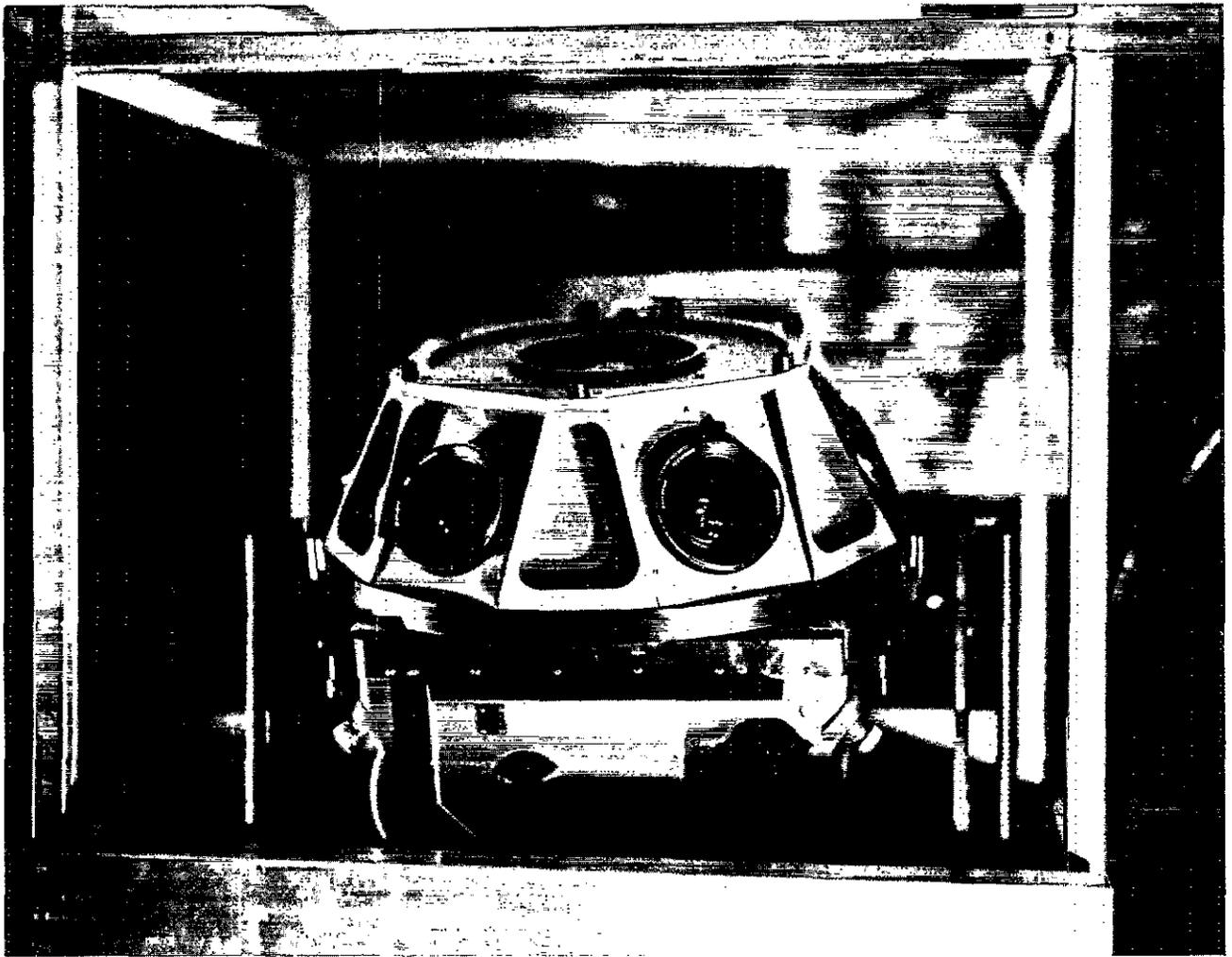Figure 1 Production of Moving Scene from Still Scene

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FIGURE 2   THE SEVEN-LENS AERIAL CAMERA

FIGURE 3   A TYPICAL TERRAIN EXPOSURE

which move as the terrain is photographed are treated as stationary anomalies or are removed during the record process.

(b) Record Processor System

The record processor system (Fig. 4) converts the photographic image into video signals for recording on Video Tape Recorders (VTR). A flying spot scanner is used to scan the 9" film roll to provide a pixel resolution of approximately 4000 pixels in both horizontal and vertical directions. Because of the size of the film and separation of the seven views, scanning is done in steps. All of the seven views are assembled in a pseudo-film plane using a resolution-preserving mathematical transformation. The video in the primary colors of red (R), green (G) and blue are digitized, and formatted such that each terrain scene is made up of several NTSC frames (typically 72). Appropriate sync signals are inserted to make the signals suitable for recording on standard 1 inch video tape recorders and laser disks. To obtain faster access during playback, pieces of a complete scene are stored in three different videotapes. During the record process, opportunity is afforded to manipulate the luminance gain and color balance of each view in every scene so that a) the edges of the view exposed by all the seven lenses match up b) successive scenes have their color and brightness matched. The key to this processing is a luminance and color corrector block together

with the large, fast semiconductor memory called the scene storage system (SSS) which can store upto 256 National Television System Commission (NTSC) frames.

(c) Photographic Film Edit System

Using highly accurate photogammetric techniques (2), the eyepoint of every scene is determined. This information aids in the proper sequencing of the scanned scenes on the tape recorders. The knowledge of accurate eyepoints also allows matching one distorted scene to another when both scenes are viewed from the same intermediate pilot position.

(d) Video Disk

The data base recorded on the video tape recorders is transferred to video disks suitable for playing on the Disco Vision 720 industrial optical disk player. Each of the video disks can store up to 54,000 standard NTSC frames or approximately 700 color visual scenes. Both frame identification numbers and Society of Motion Picture and Television Engineers (SMPTE) Codes are used for the proper sequencing of the frames.

New data bases can be created simply by going through the above steps of aerial photography, scanning, recording, disc mastering and photogammetry in the proper sequence. Therefore, there is virtually no limit to the expandability of the gaming area.
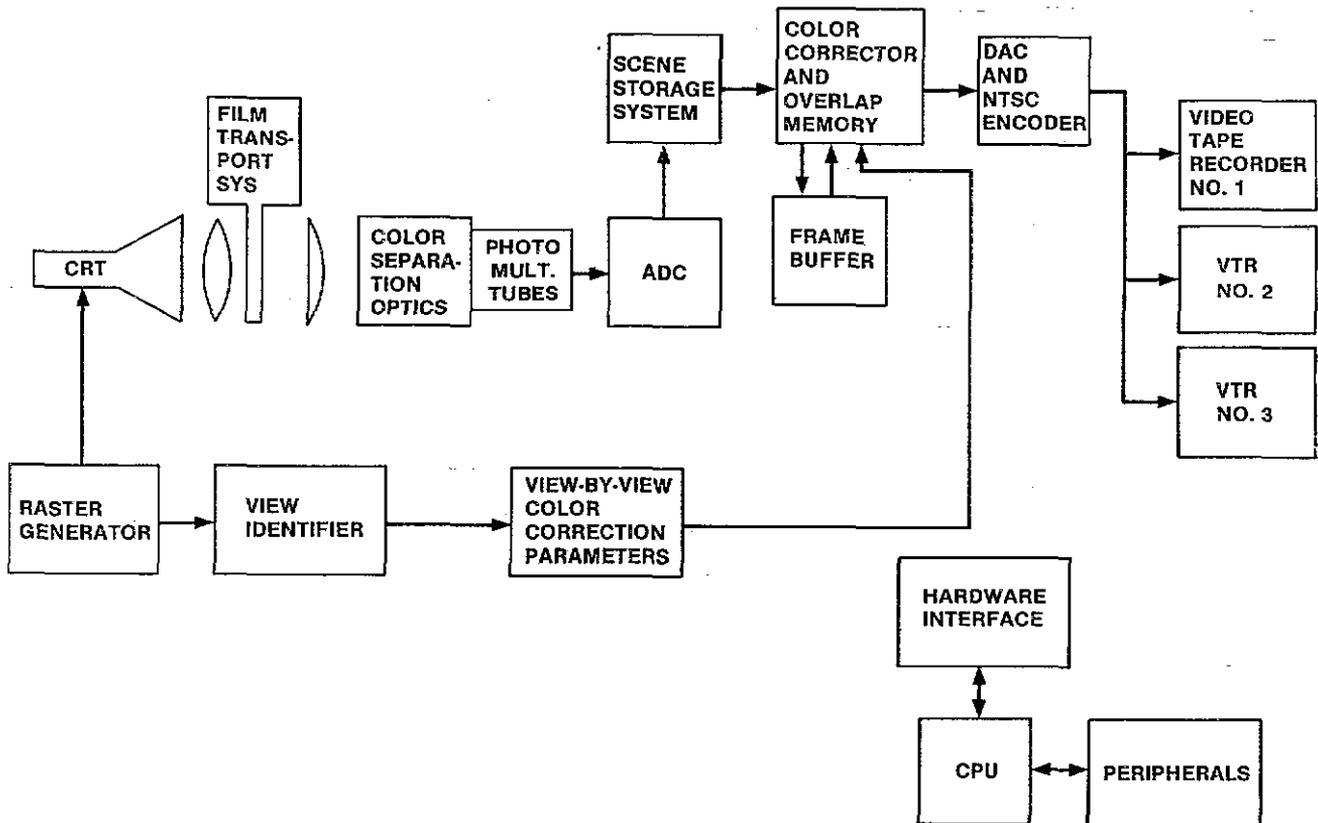

Figure 4. Record Processor System

IV. ON-LINE PLAYBACK SYSTEM

The real-time on-line playback system (Fig. 5) consists of the following subsystems.

(a) Video Storage System

Analog storage using television techniques is a practical and economical alternative to digital storage and is especially suited to pictorial data. The purpose of the storage system consisting of the sixteen video disks is to provide large segments of the desired data under control of the host computer in anticipation of the real time needs of the simulation. The bulk data is distributed over the sixteen disks to optimize the retrieval of the desired data. Any randomly accessed TV frame on a single play-back unit can be located and made available in 2 to 8 secs. Adjacent or sequential frames require much less time than this, however. The players operate essentially independently and are rotationally synchronized to the system timing references for color subcarrier and horizontal/vertical raster scans. In operation, all these units do not supply data at the same time. Data is transferred from only three players at a time while the others are searched for the anticipated subsequent scenes.

(b) Video Digitizer System

The Video Digitizer System (VDS) (Fig. 6) is the functional unit which processes analog composite video from the Video Storage System (VSS) and sends digitized video to the scene storage system (SSS). The VDS has three identical channels since at any given time three video disc players can be simultaneously accessed. The quasi-NTSC video from the VSS is read, time base corrected, clamped and digitized in the VDS. Composite video to component video conversion and spatial compression of the digitized video are carried out by the luminance and chrominance processors in an
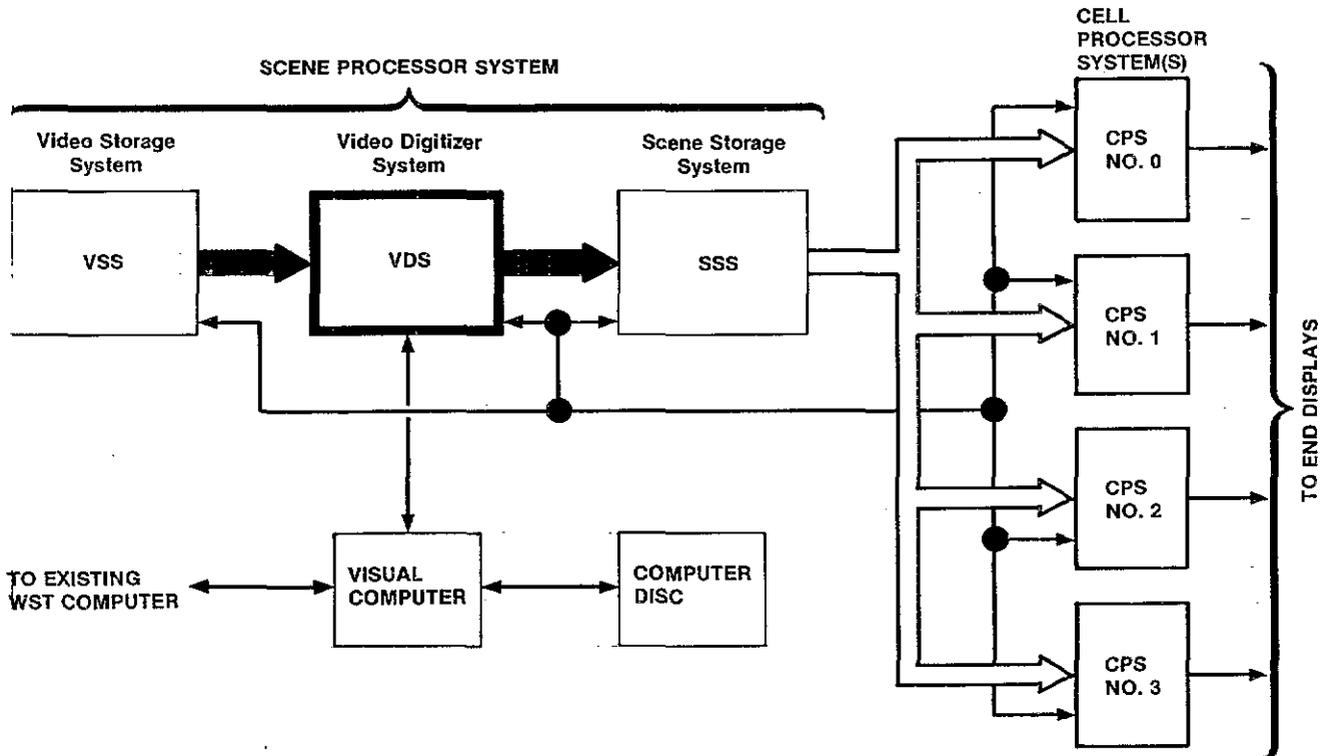
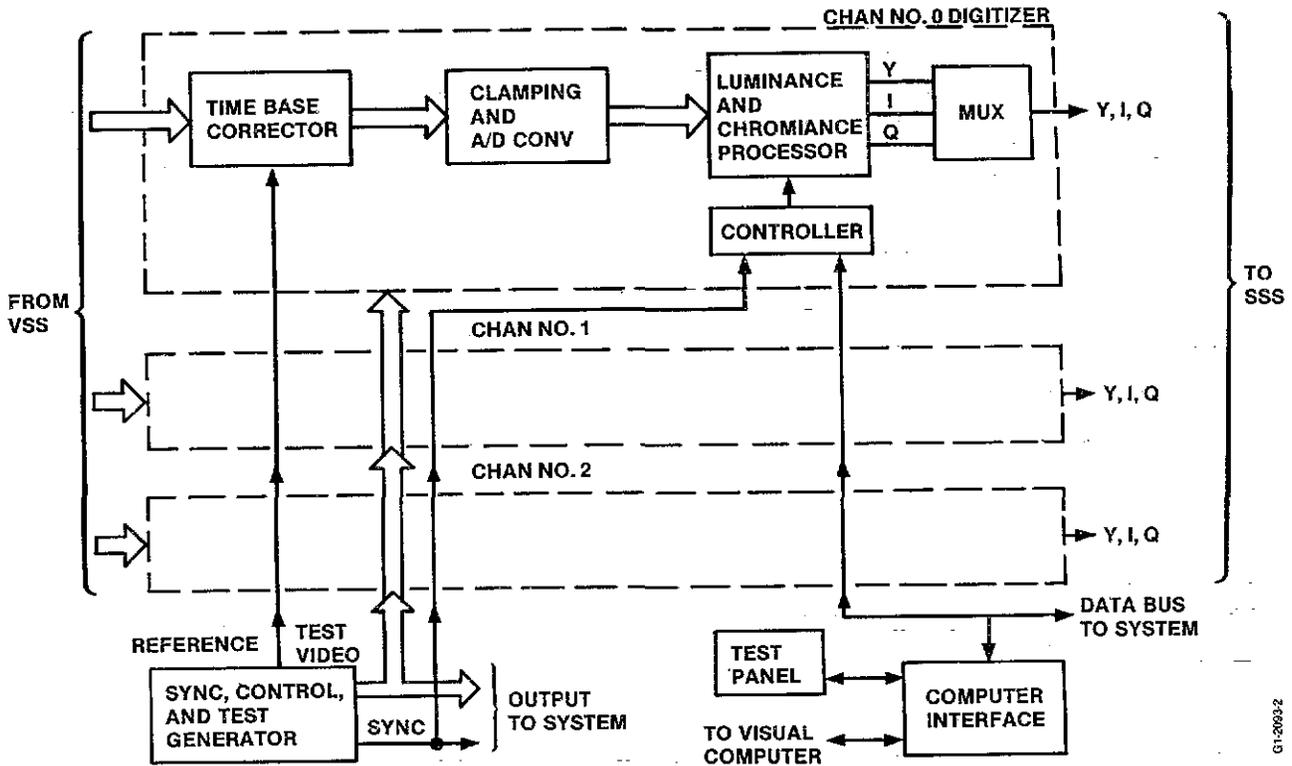

Figure 5. Visual On-Line Playback System

Figure 6 Video Digitizer System

effort to take advantage of the redundancy present in the I and Q components of the color signal and to save memory storage space in the SSS. The VDS also provides the interface between the visual system computer and the rest of the visual system hardware.

(c) Scene Storage System

The SSS comprises of two identical sections- upto 128 tracks each. Each track has the capacity to store digital video information including color, present in one NTSC TV frame (1/30 sec.). Video information can be written to one section while it is read from the second section. When fresh data is required, the input side becomes the output side and vice versa. Three channels of data can be input to the SSS and the SSS in turn can provide multiplexed Y, I & Q digital data to the 4 cell processor systems simultaneously.

(d) Cell Processor System (CPS)

The cell processor system receives the digital luminance and chrominance data corresponding to a scene photograph from the SSS. Under software control it selects the portion which is visible to the pilot through one window, performs the geometric transformation on this data as required by motion of the pilot's eyepoint, and generates analog red, green and blue video signals for

display. Data is received from the SSS by four input interpolators which operate independently and simultaneously (Fig. 7). Each of the inter- polators channels the Y, I & Q into separate data streams, performs low-pass-filtering, and inter- polates or decimates as required to provide data at the proper rate to be loaded into the cell memory. Filtering and interpolation are done in both longitudinal and transverse directions, and the parameter controlling these operations is supplied by the visual computer.

The cell memory consists of two sections. One section may be read for display while the other is being loaded by the interpolators. An output multiplexer selects the data from the appropriate section and provides it to the output processor.

The addresses for the Cell Memory are provided by the Address Generator. The read addresses are obtained from the display-raster pixel coordinates by a transformation corresponding to a piecewise continuous rotation, skew, and magnification in order to create a display of the scene data as seen from the pilot's eyepoint.

The output processor receives data through the memory multiplexer, performs the conversion from Y, I, Q format to Red, Green, Blue format, performs low pass filtering, simulates haze, and inserts a blue sky above the horizon. It also provides for replacement of a number of pixels in
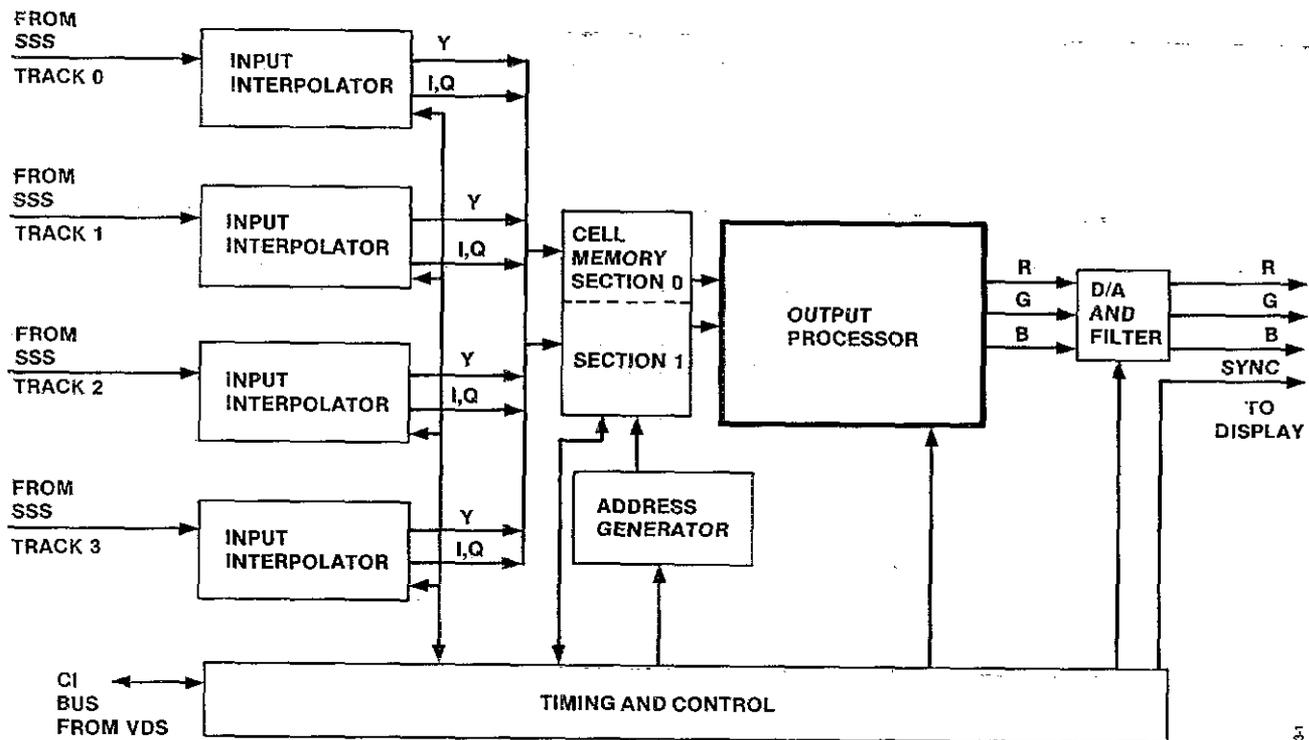
Figure 7 Cell Processor System

the output scene with pixels supplied by the Visual Computer and for insertion of a light point surrounded by a black square for the automatic position error sensing system. Finally the R, G, B digital data streams are converted to analog signals, filtered and provided to the display along with a composite sync signal.

V. IMAGE DISPLAY SYSTEM

The image display system consists of a multiple rear screen television projection system providing essentially the total forward hemisphere field of view (FOV) available from the A7-E cockpit. This is obtained by joining together six flat projection screens into a single mosaic. The total FOV and the FOV of each channel is depicted in Figure 8. Each separate rear pro-
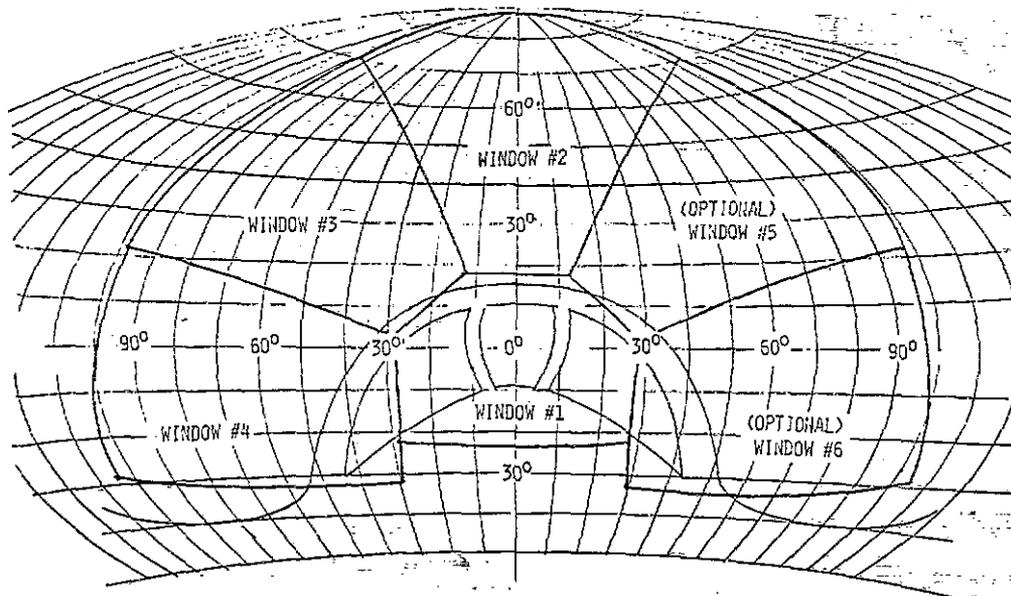

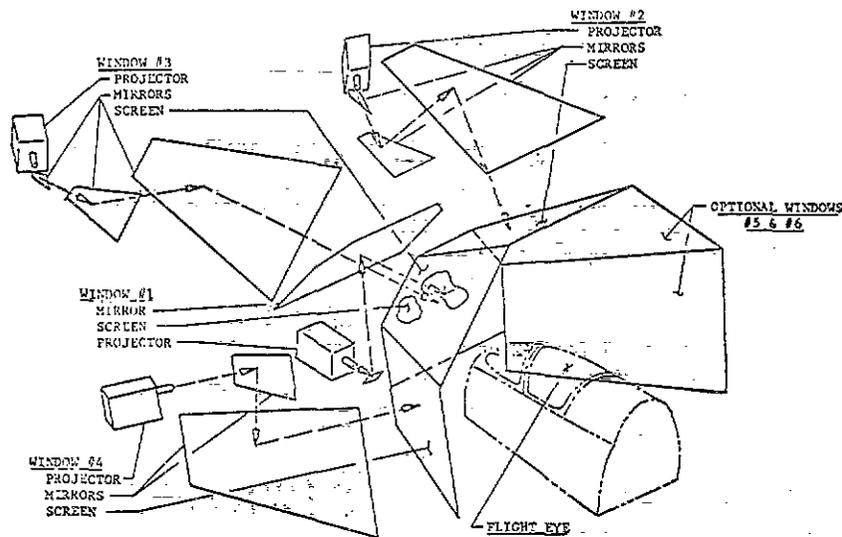FIGURE 8 DISPLAY SYSTEM FIELD OF VIEW

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FIGURE 9 A7E WST VISUAL SYSTEM

EXPLODED VIEW

jection channel consists of an 875 line General Electric Light Valve TV projector, two or more folding mirrors and a lenticular rear projection screen. The overall system design is depicted in Figure 9.

VI. CONCLUSION

CAPTV offers some major advantages over the CGI visual system. Some of these advantages are its ability to provide scene-realism, detail, 3-dimensionality, and texture that is limited only by photography and virtually unlimited for expandability of data base. The real-time play back system, when added to the existing WST equipment, will provide the pilot with a continuous display of the gaming area as presented on a hemispherical rear screen projection system. The scope of the gaming area is large enough and flexible enough for a simulator pilot to fly a mission with total maneuvering freedom. Registration with the radar, FLIR, and projected map display in the WST will be maintained regardless of the simulated aircraft maneuvers throughout the flight.

VII. REFERENCES

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